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STONEMAN II TEST OF RECLAMATION PERFORMANCE

VOLUME II

PERFORMANCE CHARACTERISTICS OF WET DECONTAMINATION PROCEDURES

Research and Development Technical Report USNRDL-TR-335

21 July 1960

by

W. L. Owen
J. D. Sartor
W. H. Van Horn

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

SAN FRANCISCO 24 · CALIFORNIA

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ABSTRACT

The basic decontamination procedures (firehosing, motorized flushing, and scrubbing) evaluated during the STONEMAN I field tests in 1956 provided a generally high fallout removal effectiveness of 98 percent or more. This was due to the visual rate-control which allowed the recovery operations to progress only as fast as the simulated fallout material appeared to be removed. For this reason the cost of recovery approached the maximum in terms of effort and water requirements.

Since in many situations there may not be adequate water supplies available for large-scale decontamination operations, it appeared desirable to lower the water consumption and also the manpower effort, and supply requirements to determine the influence on the decontamination effectiveness. A series of tests was, therefore, conducted to improve the performance of wet decontamination procedures. Synthetic fallout made of tagged processed soils was dispersed over pavements and roofs so as to simulate the deposition of actual fallout resulting from land surface detonations of nuclear weapons. Removal effectiveness and effort data were obtained on motorized flushing and firehosing of paved areas. Direct firehosing with fan-shaped streams and lobbing of standard firestreams were performed on roof areas.

The performance of motorized flushing was superior to that of firehosing both from the standpoint of removal effectiveness and effort expended. Portland cement concrete surfaces were consistently easier to clean than asphaltic concrete for either type of decontamination procedure. An improvised street flusher attachment was found to be satisfactory and its performance was competitive with the conventional flusher tested.

For roofing surfaces no rougher than composition shingles, lobbing of firestreams from ground level appears to offer the same degree of removal effectiveness as direct hosing at roof level - where roof slopes provide adequate drainage.

A mathematical model based upon theoretical considerations has been developed for the comparative evaluation of decontamination methods. With this model it is possible to assess wet decontamination methods and to estimate the effect of various environmental parameters.

SUMMARY

The Problem

To develop and evaluate reclamation techniques for land targets with emphasis on wet decontamination procedures such as motorized flushing and firehosing.

Findings

Using processed soil as a synthetic representation of the dry fallout from nuclear weapons detonated on a land surface, removal effectiveness and effort data were collected during the evaluation of four basic procedures. Decontamination of large paved areas was accomplished by motorized flushing (conventional and improvised) and improved firehosing techniques. Composition shingle and built-up tar and gravel roofs were subjected to the direct action of fan-shaped streams provided by standard firehoses equipped with special nozzles. Lobbing of firestreams onto composition shingle roofs from ground level was also tested.

The performance of motorized flushing was superior to that of firehosing both from the standpoint of removal effectiveness and effort expended. Portland cement concrete surfaces were consistently easier to clean than asphaltic concrete for either type of decontamination procedure. The improvised street flusher design was found to be feasible and its performance was competitive with the conventional flusher tested.

For roofing surfaces no rougher than composition shingles, lobbing of firestreams from ground level appears to offer the same degree of removal effectiveness as direct hosing at roof level where roof slopes provide adequate drainage.

A mathematical model based upon theoretical considerations has been developed for the comparative evaluation of decontamination methods. Using this model it is possible to assess wet decontamination methods and to estimate the effect of various environmental parameters.

ADMINISTRATIVE INFORMATION

This investigation was sponsored by the Department of the Army as part of Program B-3, Problem 3, described in this Laboratory's Technical Program for Fiscal Year 1959, revised 1 January 1959.

The main objective was to determine cost and performance of reclamation measures for land-based construction. This report presents results for the sub-objective: to provide information on new reclamation techniques for land targets with emphasis on wet decontamination procedures. The other reports in this series are

Vol. I	The Production, Dispersal and Measurement of Synthetic Fallout Material
Vol. III	Performance Characteristics of Dry Decontamination Procedures
Vol. IV	Performance Characteristics of Land Reclamation Methods
Vol. V	Contaminability Characteristics of Personnel Exposed to Contact Beta Radiation

ACKNOWLEDGEMENTS

The objectives of this test could not have been fulfilled without the whole-hearted assistance and cooperation of many organizations and personnel therefrom. The performance of the 50th Chemical Service Platoon, U.S. Army, assigned to support the test was outstanding in every respect. The services of the personnel from the Mobile Construction Battallion Five, Port Hueneme, California proved invaluable in the operation of heavy equipment assigned to the project. In addition the authors wish to acknowledge the invaluable aid from the following organizations: Headquarters, Sixth U.S. Army, Presidio of San Francisco, California; Post Engineer, Camp Stoneman, California; Research Directorate, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The first experimental work on the decontamination of paved areas and roofing surfaces which were contaminated with a dry fall-out simulant was carried out in 1948. In Operation Streetsweep[1] an investigation was made to determine the effectiveness of a mechanized street sweeper and a standard firehose in the removal of large and small sized metallic particles from various types of road surfaces. In Operation Supersweep[2] a study was made of the effectiveness of hand sweeping and hosing in the removal of three different particle size ranges of radiotantalum metal from macadam and concrete test samples. It was found in both of these experiments that the "wet" method was the more effective in removing the particles. At Operation JANGLE[3] in the winter of 1951, experiments were carried out on an asphalt road and on several buildings that were contaminated with a dry fallout from an underground nuclear detonation. A subsequent analysis of the data from these tests by Miller[4] indicated that they were insufficient for proper evaluation of the methods. Of the "wet" methods evaluated, however, it was found that high pressure hosing was the most effective.

In 1956, the basic decontamination procedures (firehosing, motorized flushing and scrubbing) were evaluated during the STONEMAN I field test[5] utilizing tagged soils to simulate dry fall-out. Generally high recovery effectiveness (less than 2 % remaining) was obtained at this series of tests. This was largely due to the visual rate-control employed in all recovery procedures. The work was allowed to progress only as fast as the contaminant appeared to be removed. This procedure resulted in large expenditures of effort associated with slow rates of operation and therefore the cost of recovery was very high in terms of effort and water requirements. For instance, an average firehosing operation required 800 gallons per 1,000 ft^2 and motorized flushing 500 gallons per 1,000 ft^2. With these water requirements, in a real situation there may not be adequate water supplies available for large scale decontamination operations. Therefore it was desirable to conduct tests with lower water consumption and also with lower effort in manpower and supply requirements to determine whether this would result in a proportionate reduction in decontamination effectiveness.

1.2 OBJECTIVE

The objective of the work described in this volume was "to determine the relationship between recovery effectiveness and those factors affecting operational efficiency in order to define optimum performance characteristics of the basic decontamination procedures."

1.3 SCOPE OF TEST

The tests* conducted on paved areas were limited to the evaluation of the following procedures: (1) firehosing; (2) conventional motorized flushing, and (3) improvised motorized flushing. Each procedure was evaluated for effectiveness in decontaminating asphaltic concrete and portland cement concrete surfaces.

The tests conducted on roofing areas were limited to the evaluatuon of the following procedures: (1) firehosing and (2) lobbing. Each procedure was evaluated for effectiveness in decontaminating composition shingle roofs while only direct hosing was evaluated using tar and gravel roofs.

Three contaminating conditions were selected for a dry synthetic fallout material simulating the fallout resulting from a high-yield (MT) land surface burst. These, in terms of nominal mass deposit levels, were: 10 grams/ft^2, 33 grams/ft^2 and 100 grams/ft^2. These mass levels correspond to dose rates of approximately 300 r/hr, 1,000 r/hr and 3,000 r/hr, all at one hour after burst.[4]

*A description of the test site at Camp Stoneman and the test surfaces can be found in Volume I[6] of this series.

CHAPTER 2

DESCRIPTION OF TEST PROCEDURES AND MEASUREMENTS

2.1 BASIC PRINCIPLES OF WET DECONTAMINATION

2.1.1 General Description of the Decontamination Process

Decontamination of paved and roofing areas covered with fallout from land surface bursts consists of two processes: (a) loosening and/or removal of the debris from the surface, (b) disposal of the debris.

For solid particulate fallout typical of land surface bursts, gravity is one of the chief forces holding the larger particles to the surface; for small particles other surface attraction forces may also be important. For this type of fallout most of the effort in decontamination is expended in moving the particles along a surface and/or physically lifting them off the surface. Wet decontamination procedures utilize the force of the water stream impinging upon the surface of the area to dislodge and accelerate the particles from a rest position; the resulting water flow over the surface then transports the particles to another position of rest downstream or to a nearby disposal area (sewers, sumps, ditches etc.).

Certain factors are believed to influence the effectiveness of wet decontamination methods and these can fall into two categories: environmental and operational. Environmental factors include items such as contaminant properties, surface characteristics, drainage conditions, weather conditions - factors that are not controlled by recovery teams. Operational factors, however, are more readily controlled and, within reasonable limits, may be adjusted toward gaining improved performance in the basic decontamination procedures.

Those operational factors believed to influence removal effectiveness the most are: (a) the energy of high velocity streams,

(b) the stream pattern, (c) the operating rate, (d) the design of the equipment, and (e) the procedural application. Although these factors are interrelated, they can be discussed individually.

2.1.2 Energy of Fluid Streams

From STONEMAN I tests[5] the loosening and transport of contaminant (in the form of soil particles) by the action of high velocity firehose streams was found to be confined almost solely to the impact region. For the heavy initial deposits and water flow rates used, the run-off water was not sufficient to transport the dense dirt particles much beyond the stream impact region. The movement of the particles from the area struck by the stream apparently was dependent primarily upon the kinetic energy of the water stream at the surface. The energy, W, of the stream per unit area of surface is given by

$$W = P\tau/A \qquad (2.1)$$

where P is the stream power in ft-lb/min, A is the area covered by the stream in sq ft, and τ is the time in min that the stream stays on the area, A.

The kinetic power, P, of a nozzled water jet in terms of its hydraulic parameters is

$$P = k_1 pQ \qquad (2.2)$$

where k_1 is a constant almost equal to unity, p is the nozzle pressure, and Q is the water flow rate through the nozzle. The flow rate, Q is equal to the product of the nozzle tip area times the jet velocity; also, Q varies as $p^{1/2}$. If these relationships are substituted in Eq. 2.2 and then into Eq. 2.1, it becomes

$$W = k_2 a p^{3/2}(\tau/A) \qquad (2.3)$$

or

$$W = k_1 a p V(\tau/A) \qquad (2.4)$$

where k_2 is a constant, a is the nozzle tip area, and V is the jet velocity. Eq. 2.3 shows that for a given nozzle tip area the energy increases as $p^{3/2}$ and hence it would be advantageous to use the highest possible nozzle pressure. On the other hand, it is desirable to keep the flow rate down to conserve water. This can be done by decreasing the nozzle tip area. Since the tip area can be made as small as desired, the available pressure becomes the limiting factor in achieving a given stream kinetic energy on the surface.

2.1.3 Stream Pattern

Two approaches have existed for some time with regard to stream pattern. The first is based on the tightly confined cylindrical water jets as typified by firehose streams; these are often called "hard" streams. Such streams deliver maximum impact per unit surface area, especially at close range (6 to 8 feet), before the jet has had a chance to spread. Effective cleaning by streams of this type diminishes at the fringe of the impact region.

The second approach to stream pattern has been that represented by flat-wide jets. These streams strike the surface in a broad but thin front and make contact with the particles essentially along the line of the stream front. Such an action seems to make best use of the available water in transmitting its energy to the maximum number of particles. On the other hand, this pattern is not believed to provide adequate water flow to transport large quantities of particles.

It appears that a combination of the best features of each pattern would give a stream providing maximum removal potential.

2.1.4 Operating Rate

The operating rate, R, is the same as A/T of Eq. 2.1. Substituting it in Eq. 2.3 gives

$$W = \frac{k_2 a p^{3/2}}{R} = k_3\, p^{3/2}/R \tag{2.5}$$

where $k_3 = k_1 a$, since a is constant for a given nozzle. Thus the total stream energy applied to the area covered by the stream is inversely proportional to the rate. If the energy required to displace a unit mass of particles from the area A is w', and the amount displaced is M_o-M (M_o is the initial mass deposited in gms/sq ft and M is the mass of particles per unit area not displaced), then the energy required for the displacement is

$$W' = w'(M_o - M) \tag{2.6}$$

For W' and W to be equal, the correct value of R must be selected. If R is too low, water is wasted. If R is too large, M will increase.

If the ratio W'/W (required energy to applied energy) is defined as an efficiency, ϵ, then the rate required is given by

$$R^* = \frac{\epsilon\, k_3 p^{3/2}}{w'(M_o - M)} \qquad (2.7)$$

Equation 2.7 indicates that, for a constant ϵ and w', the required rate varies directly with $p^{3/2}$ and inversely with M_o-M. This disagrees with the data in Appendix A where, for a given value of M_o-M (approximately), R varied as $p^{1/2}$ for firehosing nozzles. However, for motorized flushing the rates appeared to approach the pressure dependence given by Eq. 2.7. For R to vary as $p^{1/2}$, ϵ must have been inversely proportional to p. In actual practice, this means that the rate used was slower than could have been used and that it fell off the ideal rate further as the pressure was increased.

The efficiency defined by Eq. 2.7 is only an approximation of a true definition. The process by which the stream energy is utilized to accelerate particles is a complex one involving hydrodynamic parameters and energy exchanges that are more involved than the simple terms of Eq. 2.7. Another definition is discussed in Chapter 4 where the effects of an increase of M and M_o and decrease in R (for firehosing) with distance is discussed.

2.1.5 Equipment Design

Alterations or new developments in the design of decontamination equipment offer unlimited opportunity for improving the performance of recovery operations. In addition to a change in nozzle tip area, consideration must be given to nozzle attack angle (the acute angle of the nozzle relative to the surface being decontaminated), particularly with regard to motorized flushers having fixed nozzles.

Because the purpose of using hard streams is to impart their kinetic energy to contaminant particles in such a way that these particles are trajected well ahead of the approaching impact region, angle becomes most important. In transmitting a maximum trajectory a rather flat angle is required. Except for the presence of surface roughness, this optimum angle theoretically would be zero. Thus some positive angle must be employed to provide a vertical impact component for accelerating particles that are lodged in surface depressions.

A parallel consideration is that of nozzle range, the distance between nozzle tip and the contaminated surface. An increase in the useful work done by water jets could possibly result from shortening the range. This would have the effect of using the harder portion of the stream where velocity and hence the available kinetic energy are the greatest. The optimum range is believed to vary with nozzle characteristics, since it would be influenced by stream pattern.

2.1.6 Procedural Application

This factor is concerned with the movement of men and equipment which affect the performance of a recovery procedure. For instance, the progression of a decontamination operation in the direction of natural drainage is one example of good procedural application. Hosing of roofs in the direction of the eaves is another. These and other applications result in improved effectiveness and/or savings in effort required.

Of special interest is the relation between effort and effectiveness, particularly from the standpoint of increased rate since such an increase reduces effort. The rate used thus far has been the operating rate for an individual pass which only involves a few minutes time. However, the rate most sensitive to procedural application is the over-all or planning rate of an entire decontamination operation involving several hours. It is always less than the operating rate due to time lost in shut downs, direction changes and the general movement of men and equipment. By minimizing these losses the planning rate may be speeded up to more nearly match the operating rate.

With motorized flushers, the planning rate could be greatly increased, if flushers were permitted to flush upgrade as well as down. This would reduce non-productive road time which is part of the over-all operation time.

Improvement in personnel safety is another form of good procedural application. Because of the ever-present hazard to decontamination team members of falling while working on roofs, a recovery technique of lobbing fire streams from ground level up onto roof areas appears worthy of investigation. Admittedly, such an approach is not expected to afford the same degree of effectiveness as direct application of hard streams. However, lobbing should be of significant value on steep roofs (particularly metal ones) since the conditions creating the danger of slipping and falling also enhance the removal of particles by water flow. Thus the success of lobbing should be the greatest where the need for a remote technique is also most desirable.

2.2 PRODUCTION OF SYNTHETIC FALLOUT

The design and preparation of the synthetic fallout used in the tests is described in detail in Volume I[6] of this series of reports. A brief resume follows:

The dry fallout simulant was prepared by combining a radioactive tracer in solution and a bulk carrier material in the mixing drum of a modified Jaeger 3-1/2 cubic-yard transit-mix truck (Fig. 2.1). The solution was fed to an air nozzle located in the head of the rotating drum where it was atomized onto the bulk carrier materials.

The mix for each day was obtained by blending three size fractions of the bulk carrier material. The procedures for the mixing and the activity-mass distribution curves for each day's batch are presented in Volume I.[6] The mix number used for each test is indicated in Appendix C.

2.2.1 Selection of Radioisotope

The radionuclide La^{140} was used as the radioactive tracer in the synthetic fallout. Experiments[7] performed prior to the land target tests[5] conducted in 1956, demonstrated that trivalent La^{140} was strongly adsorbed to the carrier material and would not desorb under wet decontamination procedures. The half-life, 40.2 hours, was such that natural decay reduced the radioactivity at the test site to negligible amounts within a short time after the completion of the tests.

The facilities at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico were used to supply the necessary quantities of La^{140}.

2.2.2 Bulk Carrier Material

Soil (Ambrose Clay Loam) obtained from the test site at Camp Stoneman, was used as the bulk carrier material in the synthetic fallout. To obtain acceptable physical properties, the soil was processed through a crushing, burning and sieving operation by a commercial materials processing plant.

2.3 DISPERSAL OF SYNTHETIC FALLOUT

The amount of synthetic fallout material dispersed depended upon the radiation levels simulated. As stated in Section 1.4, it was desired to simulate radiation dose rates of 300 r/hr, 1,000 r/hr, and 3,000 r/hr, at 1 hour after burst, by depositing nominal mass levels of approximately 10 gms/ft^2, 33 gms/ft^2 and 100 gms/ft^2, respectively. Because of the equipment used precision spreading of the contaminant was not possible; therefore these nominal mass loadings were not always achieved. Tables 3.1-3.5 show the average initial mass levels actually obtained for each test.

The layer of material (based on soil density of 1940 lbs/yd^3) simulating 300 r/hr at 1 hour would be approximately 0.004 inches deep; for 1,000 r/hr at 1 hour, 0.012 inches deep; and for 3,000 r/hr at 1 hour, 0.04 inches deep.

2.3.1 Pavements

The dry synthetic fallout was dispersed over the paved areas from a modified Burch Hydron Spreader mounted on the rear of a 2-1/2 yd^3 dump truck (Fig. 2.2). An aluminum hopper was installed on the truck to contain the synthetic fallout material and feed it directly into the spreader when the truck bed was raised. The dimensions of the test areas are shown in Appendix B.

2.3.2 Roofs

The dry synthetic fallout material was dispersed over the roofing areas from hand-drawn spreaders (Fig. 2.3). The various test areas are indicated in Appendix B.

2.3.3 Sampling Pans

To determine the actual quantity of material dispersed, sampling pans (Figs. 2.2, 2.3) were placed on the test area prior to the dispersing of the synthetic fallout material. These pans were collected immediately after the disperser had passed over them, placed in plastic bags, and weighed.

The total activity of the sample in the pan was determined in a large sample counter (LSC). The LSC consisted of a chamber 26-in. wide by 28-in. deep by 52-in. high, covered with 2-in. lead sheet and lined with 3/4-in. plywood, into which the pan was placed. A 2-1/2-in. sodium iodide-thallium activated crystal detector, attached to an appropriate scaler was used to count the sample. Next, a portion of the material in each pan was removed for the determination of specific activity in the 4-pi ion chamber.[8]

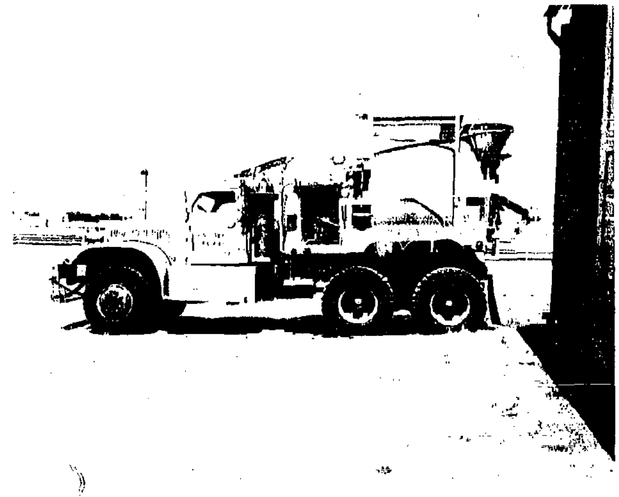

Fig. 2.1 Transit-Mix Truck for Mixing Dry Synthetic Fallout Material

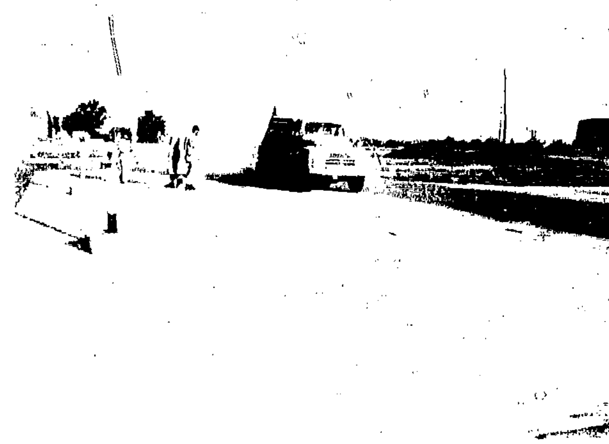

Fig. 2.2 Dump Truck for Dispersing Dry Synthetic Fallout on Pavement. Sampling pans collect samples for determining actual quantity dispersed.

Fig. 2.3 Hand-drawn Spreaders for Dispersing Dry Synthetic Fallout on Roofs

2.4 DECONTAMINATION TESTS

2.4.1 Preliminary Studies

Prior to the field test itself, a series of engineering-scale studies were conducted to study some of the engineering parameters believed to affect decontamination effectiveness. These studies included:

a. Water stream impact as a function of nozzle pressure and range.
b. Designing an improvised nozzle system for a street flusher.
c. Determining the most efficient stream pattern produced by various hand-held nozzles for the removal of soil particles.
d. Designing a suitable nozzle for direct firehosing of roofs.
e. Determining operating parameters for the motorized flusher, i.e., pump pressures, nozzle attack angles, nozzle orifice size, and rate of operation.

The preliminary studies were conducted on an asphalt street and concrete pavement located in the San Francisco Naval Shipyard.

Dry soil of the type used in the synthetic fallout was dispersed on the areas in concentrations of 100 g/ft^2. A few tests were made with the street flusher at smaller concentrations, 10 and 30 g/ft^2, respectively. No radioactive tracer was used and the removal effectiveness was qualitatively evaluated by visual observations. Results and details of the preliminary studies are given in Appendix A.

2.4.2 Field Test Procedures

2.4.2.1 Pavements

Firehosing

The firehosing procedure (Fig. 2.4) on paved areas was evaluated on asphaltic concrete and portland cement concrete test areas. The procedure was carried out with two standard 1-1/2-in. firehoses fed by a 2-1/2-in. firehose running from a nearby fire hydrant to the test area. A 500-gpm pump was inserted in the hose line near the hydrant to maintain a constant nozzle discharge pressure of 75 to 80 lbs/in^2 for all of the tests. A standard 1-1/2-in. fire nozzle with a 5/8-in. orifice was attached to each 1-1/2-in. firehose.

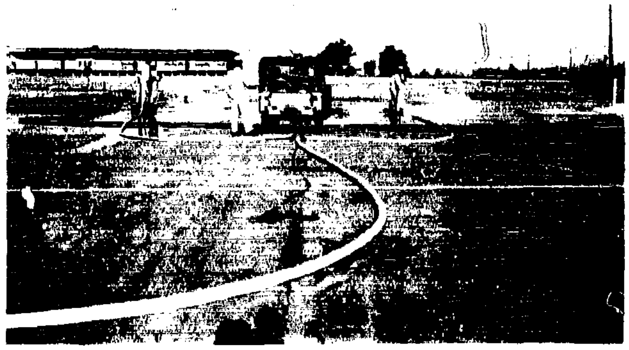

Fig. 2.4 Firehosing on Portland Cement Concrete Pavement
A. Arrangement of equipment and personnel.
B. Stream striking surface.

A firehosing team utilized five personnel: two nozzle men, two hose men and the fifth man driving a jeep which towed the 2-1/2-in. firehose as the procedure progressed down the area.

The procedure started at the higher end of the slope and proceeded down the length of the test area. The nozzle men advanced side by side pushing the contaminant ahead and to each side, directing the stream to impinge upon the area 15 to 20 feet down the area.

From the preliminary studies (see ~endix A) it was found that by directing the stream to impinge 15 to 20 feet down the area, the removal rate increased 33 to 43 percent over that when operating at a range of from 6 to 8 feet. This increase in operating rate also resulted in a considerable decrease in unit water consumption (gal/ft^2).

These studies also indicated that the best stream pattern for efficient removal when the stream impinges at the longer range was provided by the 5/8-in. orifice, which was available on the standard 1-1/2-in. firehose nozzle. A nozzle calibration curve for this nozzle is included in Appendix A.

Conventional Motorized Flushing

The conventional motorized flushing (CMF) procedure (Fig. 2.5) was carried out with a conventional street flusher of 3000-gal capacity, equipped with a 500-gpm pump and two forward and two side discharge nozzles. The truck was driven down the slope of the long dimension of the test area, the first pass being made along the high side of the cross slope. Successive adjacent passes covered the full width of the area.

Upon the basis of the preliminary studies described in Appendix A, the maximum available nozzle pressure of 55 psi was employed with nozzle orifices set at 1/16 inch.

In order to push the particles to one side and out of the way of the truck's wheels and to conserve water and attain a high pressure, only three of the four available nozzles were used at one time. The two front nozzles were adjusted so that their jets intersected the pavement in a continuous straight line. This line was canted at an angle of about 60° to the line of travel, in accordance with the findings of the preliminary tests. The left side nozzle (behind the driver) was aimed so as to pick up where the left front nozzle left off in the removal process (see Fig. 2.5). A calibration curve for the flusher nozzles is included in Appendix A.

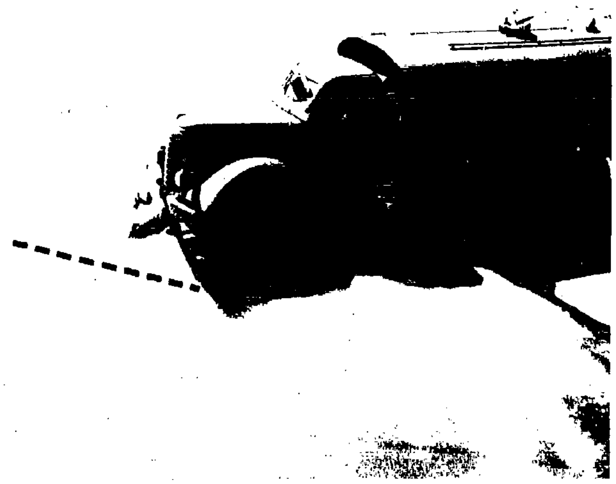

Fig. 2.5 Motorized Flushing on Asphaltic Concrete Pavement. Note that the two forward nozzles are adjusted so that their streams strike the pavement in a straight line.

To determine the effect of effort on the removal effectiveness, the motorized flusher was operated at three different rates. These rates of operation depended upon the nominal mass levels and were chosen from the curves presented in Fig. 2.6, prepared during the preliminary studies.

An accurate speed indicator mounted on the dashboard, leading from a fifth wheel attached to the flusher, allowed the driver to maintain a constant speed of operation.

Improvised Motorized Flushing

For the improvised motorized flushing (IMF) procedure (Fig. 2.7), the street flusher used for the motorized flushing procedure was provided with an improvised nozzle bar replacing the two forward flushing nozzles. The operating procedure was similar to that of the motorized flushing procedure; i.e., the truck was driven down the slope of the long dimension of the test area, the first pass being made along the high side of the cross slope. Successive adjacent passes were made over the full width of the test area.

The improvised nozzle bar consisted of an 8-1/2-ft length of 2-in. standard pipe having fourteen nozzles equally spaced on 6-in. centers. The nozzles were selected during the preliminary studies (Appendix A), those which gave the best stream pattern and impact characteristics, and were flat jet nozzles.* A nozzle pressure of 85 psi was maintained in all tests. Consumption curves for the nozzle bar are given in Appendix A.

The nozzle bar was attached to the front bumper of the street flusher (Fig. 2.8) so as to maintain an attack angle (between the stream and the pavement) of 30° and an azimuth angle (between the stream and the direction of travel) of 60°. Short lengths of 2-1/2-in. fire hose were used to connect the nozzle bar to the piping system on the truck.

Three different rates were evaluated as in the case of the conventional motorized flushing procedure. The curves in Fig. 2.6 were used to determine the operating speed during the full-scale tests.

*Number U-40150, Spraying Systems Co., Belwood, Illinois.

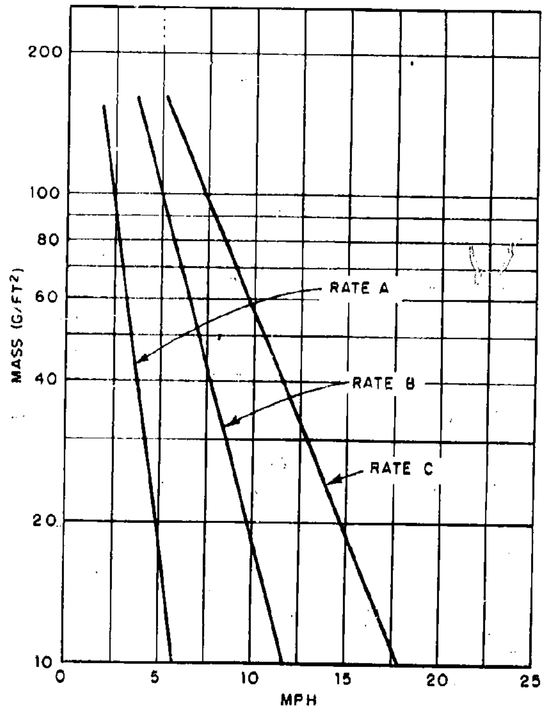

Fig. 2.6 Graph for Estimating Flusher Speeds for Various Mass Loadings

Fig. 2.7 Improvised Flusher on Asphaltic Concrete Pavement

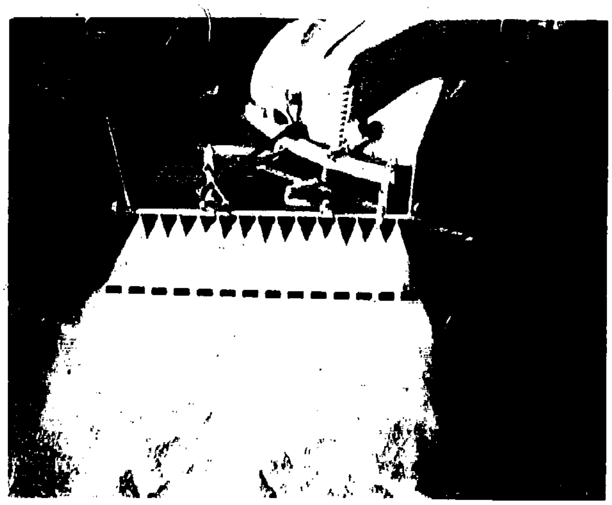

Fig. 2.8 Improvised Nozzle Bar Attached to Conventional Street Flusher

2.4.2.2 Roofs

Firehosing

The direct firehosing procedure on roofing areas (Figs. 2.9, 2.10) was evaluated on two types of roofing materials: composition shingle roofing, and tar and gravel roofing. The procedure was carried out with two 1-1/2-in. firehoses which were fed by a 2-1/2-in. firehose running from a nearby fire hydrant to the test area. A 500-gpm pump was inserted in the hose line near the hydrant to maintain constant nozzle discharge pressures of 120 and 150 psi, respectively for composition shingles or tar and gravel. A firehosing team utilized six personnel: two nozzle men, two hose men and two men to help handle the hoses on the ground.

During the preliminary studies, the development of a suitable nozzle for roofs led to one which produced a flat fan-shaped pattern (Fig. 2.11). The nozzle was designed with a 3/8 X 9/16-in. eliptical orifice. Performance curves for this nozzle are in Appendix A.

On the composition shingle roofs, the hosing was started at the peak near the end of the roof and proceeded across and down to the eaves. The nozzle operators experienced no great difficulty in working on the sloping roof.

On the relatively flat tar and gravel roofs the firehosing team worked generally from the center line out to the edge. However, on each pass they first removed the gravel nearest the eaves before cleaning the remainder from the center line. This obviated the windrowing of loosened gravel and the blocking of runoff water. Each team was responsible for only one half of the roof to avert the possibility of interference between hoses or water streams.

To determine the influence of effort on the effectiveness of decontaminating the roofs, two rates of operation were utilizd. In the first, the rate of advance was determined by the speed with which the contaminated gravel was removed. In the second, an additional pass was made over the entire area in an attempt to remove any contaminant missed during the first pass. The rate was controlled visually, the work progressing as the area appeared to become clean.

Lobbing

The lobbing procedure (Fig. 2.12) was carried out with a 1-1/2-in. firehose fed by a 2-1/2-in. firehose running from a nearby fire hydrant. A standard 1-1/2-in. fire nozzle with a 5/8-in.

Fig. 2.9 Firehose Flushing on Composition Shingle Roofing

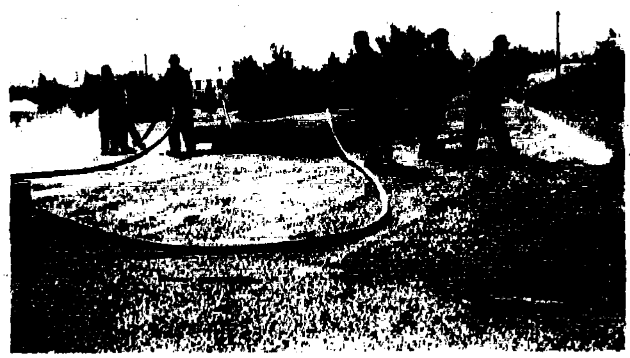

Fig. 2.10 Firehose Flushing on Tar and Gravel Roofing

Fig. 2.11 Nozzle Designed for Direct Firehosing of Roofs. Notice fan-shaped pattern.

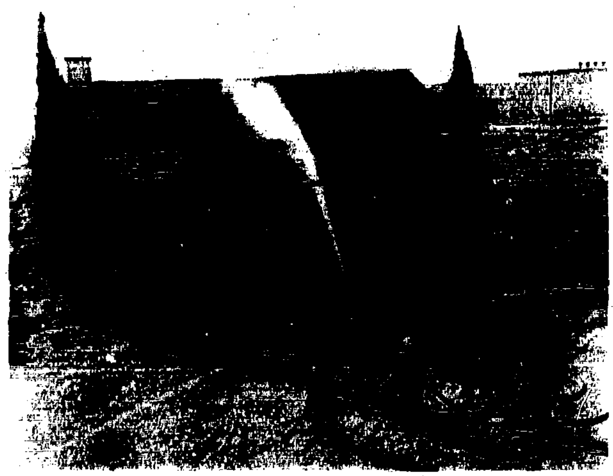

Fig. 2.12 Lobbing Firehose Stream on Composition Shingle Roof

orifice was used discharging at 40 psig. A lobbing team required 1 nozzle man and 3 hose men.

The procedure consisted of directing the fire stream onto the roof such that the stream acted as a heavy rain thus washing the contaminant down slope and off the roof. Since this procedure would be most applicable to steep roofs where the slope enhances the removal of particulate contaminant by water flow, it was evaluated on one of the taller buildings, with a composition shingled roof and having a roof peak approximately 23 feet high.

The rate of progress was determined visually, the work progressing as the run off water appeared clear.

2.5 RADIATION AND EFFECTIVENESS MEASUREMENTS

To determine the effectiveness of the various procedures evaluated, measurements were taken of the radiation levels present on the test areas just prior to contamination (background), after contamination, and after decontamination. The measurements were obtained with two mobile, shielded gamma scintillation detector units, one for paved areas "Egghead III" (Fig. 2.13) and one for building roofs "Egghead, Jr." (Fig. 2.14). The principal elements of these instruments consisted of a one-inch NaI (Tl) Scintillation Crystal on a photomultiplier tube. These were contained within a thick lead shield which was mounted so as to place the center of the detector one meter above the ground plane. A collimated aperture subtending a solid angle of view permitted entrance of radiation into the sensitive volume. The important characteristics of the two instruments are compared below. The conversion of the radiation measurements to mass units is summarized in Appendix C.

Instruments Used	Egghead, III	Egghead, Jr.
Surface type	Pavements	Roofs
Crystal size	1 inch	1 inch
Detector ht.	1 meter	1 meter
Shield thick.s.	6 inches	4 inches
Aperature diam.	1 inch	2 inches
Solid angle of view	50 degrees	23 degrees

Appendix B presents the measurements obtained at each location on the test areas. The data presented have been corrected for radioactive decay and any significant background readings.

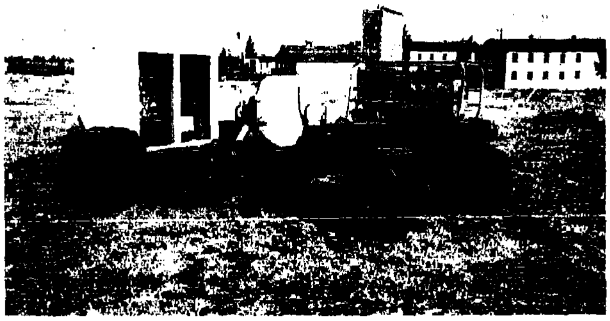

Fig. 2.13 Mobile Shielded Gamma Scintillation Detector Unit (EGGHEAD III)

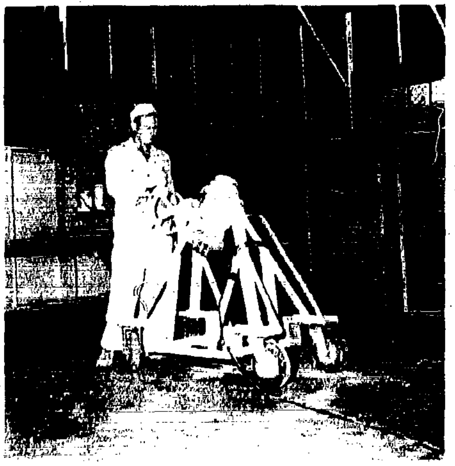

Fig. 2.14 Mobile Shielded Gamma Scintillation Detector Unit (EGGHEAD JR.) Power supply and read-out system not shown.

Each decontamination operation was timed to obtain necessary information on rate and effort. Motion pictures were also obtained of the various operations; this allowed subsequent reviewing and evaluation of the operations.

CHAPTER 3

RESULTS

3.1 DECONTAMINATION TESTS

The results of reduction of the decontamination effectiveness data for paved and roofing surfaces are summarized in Tables 3.1 through 3.5. Among each of the four types of surfaces tested, asphaltic concrete (A-C) and Portland cement concrete (P-C) pavement, and composition shingle (C-S) and tar and gravel (T-G) roofing, no great individual variation in surface characteristics was noted, and it was assumed that all surfaces of a given type were identical. The average initial mass level, M_o, and average final mass level, M, in grams per square foot are computed as shown in Appendix C from the observed data of Appendix B. The average percent remaining, $\overline{F}_m$, is obtained from the relation

$$\overline{F}_m = \frac{M}{M_o} \times 100 \qquad (3.1)$$

It should be noted that $\overline{F}_m$ can also be obtained by substituting the average final and initial radiation readings, I_R and R_R, for M_o and M respectively. Effort, E, is a measure of available power expended per unit area, normally expressed as man-min/ft^2 or equipment-min/ft^2. For the sake of convenience E is given in terms of man-min/10^4 ft^2 for pavement and man-min/10^3 ft^2 for the roofs. The observed data for computing E, given in Appendix B, consists of the size of the test area, the total time of decontamination and number of men utilized. The time does not include equipment set-up time nor turn-around time for the street flusher.

TABLE 3.1

Decontamination Results for Conventional Motorized Flushing

Test No.[a]	$\overline{M}_o$ (g/ft^2)	$\overline{M}$ (g/ft^2)	$\overline{F}_m$	Effort $\left(\frac{\text{Man-Min}}{10^3\ \text{ft}^2}\right)$
		Asphaltic Concrete		
A-1	21.2	0.86	4.1	2.47
A-2	34.0	1.45	4.3	2.66
A-3	83.9	0.79	0.9	5.42
A-4	23.0	1.39	6.0	1.33
A-5	34.7	1.41	4.1	1.83
A-5'	28.2	0.99	3.5	1.87
A-6	80.2	1.75	2.2	3.00
A-7	23.1	1.83	7.9	0.92
A-8	56.9	2.34	4.1	1.25
A-8'	38.8	1.07	2.8	1.21
A-9	110.8	5.75	5.2	1.85
		Portland Cement Concrete		
A-10	16.3	0.70	4.3	1.12
A-11	37.5	0.49	1.3	2.36
A-12	127.9	2.02	1.6	2.60
A-13[c]	16.7	0.61	3.7	1.60
A-14[c]	102.6	0.88	0.9	3.92
A-40S[b]	141.2	23.06	16.3	5.2
A-40F[b]	-	1.68	1.4	1.76

a. See Appendix B for description of tests.
b. S = Motorized Sweeping
F = Motorized Flushing
c. Extended uphill-downhill run on a street.

TABLE 3.2

Decontamination Results for Improvised Motorized Flushing

Test No.	$\overline{M_o}$ (g/ft^2)	$\overline{M}$ (g/ft^2)	$\overline{F}_m$ (%)	Effort $\left(\frac{\text{Man-Min}}{10^4\ \text{ft}^2}\right)$
		Asphaltic Concrete		
A-15	20.6	1.23	6.0	2.36
A-16	56.1	1.50	2.7	2.62
A-17	137.6	2.24	1.6	3.56
A-18	22.4	1.19	5.3	1.28
A-19	25.0	0.62	2.5	2.03
A-20	129.2	2.36	1.8	2.51
A-20'	87.2	1.59	1.8	2.13
		Portland Cement Concrete		
A-21	22.0	0.83	3.8	1.60
A-22	25.3	0.49	1.9	2.44
A-23	84.8	1.01	1.2	3.84

TABLE 3.3

Decontamination Results for Firehosing Paved Areas

Test No.	$\overline{M_o}$ g/ft^2	$\overline{M}$ g/ft^2	$\overline{F}_m$ (%)	Effort $\left(\frac{\text{Man-Min}}{10^4 \text{ ft}^2}\right)$
Asphaltic Concrete				
A-24	20.4	0.69	3.4	34.1
A-25	34.0	0.79	2.3	34.1
A-25'	31.7	0.70	2.2	46.6
A-26	138.8	1.59	1.1	83.3
A-26'	94.5	1.27	1.3	47.1
A-27	20.0	3.69	18.5	18.3
A-28	54.0	5.04	9.3	25.7
A-29	165.4	3.51	2.1	72.4
Portland Cement Concrete				
A-30	18.9	0.47	2.5	31.3
A-31	43.6	0.74	1.7	36.0
A-32	102.1	1.13	1.1	57.3

TABLE 3.4

Decontamination Results for Direct Firehosing on Roofs

Test No.	$\overline{M_o}$ (g/ft²)	$\overline{M}$ (g/ft²)	$\overline{F}_m$ (%)	Effort $\left(\frac{\text{Man-Min}}{10^3\ \text{ft}^2}\right)$
		Tar and Gravel		
AR-1	28.0	1.30	4.6	50.0
AR-2	25.6	1.55	6.1	37.5
AR-3	91.5	2.22	2.4	50.0
AR-4	21.1	3.05	14.4	38.4
AR-5	22.9	2.14	9.3	27.9
AR-6	65.2	6.87	10.5	33.4
		Composition Shingle		
AR-7	20.6	1.36	6.6	8.8
AR-8	43.7	2.58	5.9	9.4
AR-9	102.0	4.18	4.1	21.2
AR-10	10.8	1.13	10.5	4.7
AR-11	40.0	3.02	7.6	6.6
AR-12	71.8	4.43	6.2	7.5

TABLE 3.5

Decontamination Results for Lobbing Firehose Streams on Composition Shingle Roofs

Test No.	$\overline{M_o}$ (g/ft²)	$\overline{M}$ (g/ft²)	$\overline{F}_m$ (%)	Effort $\left(\frac{\text{Man-min}}{10^3\ \text{ft}^2}\right)$
AR-13	8.8	0.91	10.4	12.1
AR-14	26.2	1.06	4.0	11.3
AR-15	73.9	3.03	4.1	15.8

3.2 TIME AND MOTION STUDIES

Extensive film footage was taken of most of the tests. Efforts to obtain quantitative time information from viewing these films were generally unsuccessful, because sufficient detail was not visible. However, much qualitative information was obtained from these films which proved useful in evaluating the operational characteristics of the procedures evaluated.

CHAPTER 4

DISCUSSION OF RESULTS

4.1 PARAMETERS AFFECTING DECONTAMINATION EFFECTIVENESS

The effectiveness of a decontamination is expressed as the residual mass level remaining for a given initial mass level, or ratio of the two (called fraction remaining) after a specified expenditure of effort has been applied in decontaminating a surface. The relationship between the effectiveness and effort is the decontamination efficiency of a method-surface combination.

In the tests, the conditions of both the initial mass and effort were varied by as much as a factor of 7 or 8 for certain methods. However, the way in which these conditions were varied was not ideal from the standpoint of deducing generalized relationships between effectiveness and effort for the different methods and surfaces. For example, in Table 3.1 for motorized flushing of asphaltic concrete, the value of the effort varies along with the initial mass (one exception) and no single set of values exists where either M_o or effort is held constant and the other is varied over a large range. This occurred, of course, because one of the main purposes of the test involved conservation of water and the mechanics of the methods as discussed in Appendix A.

The dependence of the residual mass level upon initial for various decontamination techniques has been known for sometime; equation 4.1 below, was developed by Miller[9] to account for the observed variation in residual mass level with the initial level.

$$M^* = M_o^*(1 - e^{-\alpha M_o}) \qquad (4.1)$$

where M^* - residual mass level at an infinite effort level, g/ft^2
M_o - initial mass level, g/ft^2
M_o^* - the limiting upper value for M^*, a constant for a given surface-method combination, g/ft^2

α - spreading coefficient dependent upon the surface-method combination, the particle size and density of the fallout material, ft^2/g

As noted, Eq. 4.1 assumes the expenditure of a very large effort and a constant value of M_o for the surface. The latter assumption, for wet decontamination methods, restricts rigorous application of Eq. 4.1 to small areas because when these methods are applied to large contaminated areas, the particles are scattered forward and/or to the side and consequently are piled on top of the original deposit. Since M_o, and perhaps α, will increase in the forward and side directions, Eq. 4.1 would indicate an increase in M^* in those directions. If the infinite-effort residual level increases in this manner, the less-than-infinite effort residual levels should exhibit even larger increases with distance of travel.

The relative increase in M with forward distance is shown in Table 4.1 for decontamination of asphaltic concrete. The table was made up by averaging the measured residual levels across the test strips at the indicated distance along with those at the adjacent $\pm$ 12-ft distances. The ratios show no persistent trend with initial mass. The increase in M with distance, however, occurs for all methods. From 37.5 ft to 112.5 ft, the average relative increase is 31 % for the CMF, 45 % for the IMF, and 67 % for firehosing. From 37.5 ft to 75 ft, the relative increases are 18 %, 34 %, and 42 %, respectively for the 3 methods. Thus the rate of increase in M with distance decreased with distance. The average values of the residual mass given in Chapter 3 do not account for these increases of M with distance so that, with respect to the decontamination of a given square foot of area, they apply to some initial mass level greater than M_o (not necessarily coincident with the value at the center of the area).

The effort as defined in Chapter 3 given by

$$E = N/R \tag{4.2}$$

where R is the rate of area coverage and N is the number of personnel used. The gross efficiency given by Eq. 2.7, in terms of E^*, the required effort to displace the mass (M_o-M) is then

$$\mathcal{E} = \frac{Nw'(M_o-M)}{k_2 p^{3/2} E^*} \tag{4.3}$$

For a constant nozzle pressure, Eq. 4.3 can be changed to define an efficiency in terms of mass removed per unit of actual applied effort E which can be written as

$$K = (M_o-M)/E \tag{4.4}$$

TABLE 4.1

Relative Increase in M With Forward Distance in Decontaminating Asphaltic Concrete

Test	M_o	B(9)/A(9)*	C(9)/B(9)*	C(9)/A(9)*
		1. CMF		
A-1	21.2	1.075	1.295	1.391
A-4	23.0	1.233	0.874	1.077
A-51	28.2	1.442	0.954	1.375
A-2	34.0	1.102	0.898	0.990
A-5	34.7	1.129	0.933	1.053
A-81	38.8	1.043	1.136	1.185
A-8	56.9	1.119	1.423	1.592
A-6	80.2	1.265	0.936	1.184
A-3	83.9	1.320	1.576	2.083
A-9	110.8	1.067	1.063	1.135
Average		1.180	1.109	1.306
		2. IMF		
A-15	20.6	1.376	1.037	1.425
A-18	22.4	1.342	1.308	1.756
A-19	25.0	1.075	1.525	1.639
A-16	56.1	1.098	0.996	1.095
A-201	87.2	1.440	1.040	1.497
A-20	129.2	1.211	1.077	1.305
A-17	137.6	1.809	0.802	1.452
Average		1.336	1.112	1.454
		3. FH		
A-24	20.4	1.885	1.037	1.955
A-25ii	31.7	1.377	1.129	1.554
A-25i	34.0	1.420	1.100	1.562
A-25	43.4	1.437	1.137	1.633
A-28	54.0	1.390	1.410	1.960
A-261	94.5	1.152	1.338	1.542
A-26	138.8	1.362	1.088	1.482
A-29	165.4	1.346	1.227	1.652
Average		1.421	1.184	1.668

*Forward Distance: for A(9) is 37.5 ft (25 to 50)
for B(9) is 75 ft (62.5 to 87.5)
for C(9) is 112.5 ft (100 to 125)

(9) refers to number of readings contained in the average value used.

It may be recalled that, for ε to be constant, R^* was the required rate for application of the stream energy W to displace the mass, (M_o-M). On the other hand, Eq. 4.1 expresses the concept that, even with an infinite amount of applied effort, a residual amount, M^*, will remain on the surface. In this case, Eq. 4.3 does not apply since E^* cannot be infinite unless M_o is infinite. The continued application of effort beyond that required to remove the mass (M_o-M) means that most of the excess effort is wasted, or that E^* should be replaced by $(E-E_x)$ where E is the applied effort and E_x is essentially excess or wasted effort. The value of E_x should be an increasing function of E. The efficiency defined by Eq. 4.4 implies that K varies inversely with E and approaches zero as E becomes very large since M_o-M should approach M_o-M^* which is approximately equal to M_o.

An additional complication is that M_o is increasing with distance during removal and, for the average value of M for a large area, has some value actually greater than M_o. Even if this value were known, it would be desirable to express the over-all efficiency in terms of M_o itself. In each of the methods, E also changes with distance as the decontamination progresses. In the case of firehosing, the coverage rate decreases (E increases) because the firehose crews automatically tend to slow down as the mass of particles in front of them increases. In the case of the flushers, the adjacent passes tend to get narrower as the distance that the particles are moved sideways on each pass gets smaller. This build-up of mass of material on a very large paved area would be a limiting factor in the use of wet decontamination methods unless the drainage is very favorable. Without data on these interrelated effects, no logical account can be made for them in the development of an efficiency function.

In order to account in some measure for the concept of the residual level, M^*, remaining after application of very large efforts and for the decrease in the efficiency of the methods for removing mass as the effort increases, a generalized efficiency function is defined in terms of the decrease in the fractional amounts of the removable mass per unit of applied effort as follows.

$$\frac{-dM}{(M-M^*)dE} = K(E) \qquad (4.5)$$

where K(E) is an apparent efficiency factor and has the form

$$K(E) = K_o E^{-n} \qquad (4.6)$$

where n and K_o are constants. Integrating Eq. 4.5 after substituting Eq. 4.6 between the limits of M_o at zero effort and M at the effort E gives

$$M = M^* + (M_o - M^*) \exp\left[\frac{-K_o E^{1-n}}{1-n}\right] \qquad (4.7)$$

In this case M refers to the $\bar{M}$ values of Chapter 3 and M_o the initial levels without consideration of build-up to some level greater than M_o. In this treatment, all the changes occurring to reduce the apparert efficiency of the method are lumped into the selected functional form for K(E).

Preliminary treatment of the data gave values of n between 0.6 and 0.7. Because of the scatter in the data, the single value, 2/3, was used for all three methods. Equation 4.7, in final form, is

$$M = M^* + (M_o - M)^* \exp\left[-3K_o E^{1/3}\right] \qquad (4.8)$$

where M* and K_o are the parameters dependent on the method and/or surface.

The foregoing derivations assume a permanent, non-changing surface; actually surfaces such as asphaltic concrete erode while being decontaminated, but this factor is unimportant in the range of practical interest.

Final values of M* and α were derived by using successive approximations of M*, first in Eq. 4.8 and then in Eq. 4.1, ultimately obtaining values of M*, M_o^* and α which fitted the requirements of both sets of equations. This derivation was simplified for the asphaltic concrete and portland cement concrete surfaces by the application of data from STONEMAN I. In the STONEMAN I test series very high effort levels were employed in an attempt to obtain the best possible decontamination with a given method. It was assumed, that these values of M approached the theoretical M* value. These data, shown in Figs. 4.1.1 and 4.1.2, do appear to correlate quite well with the theoretical curve. Figure 4.1.3 also shows STONEMAN I data, but the correlation is weaker. However, because the absolute mass levels were not accurately determined at STONEMAN I, no attempt was made to differentiate between firehosing and motorized flushing.

Using values of M* from Figs. 4.1.1, 4.1.2 or 4.1.3 (each being based on Eq. 4.1) Eq. 4.8 was evaluated for the various experimental cases. The resulting curves of the mass level M, in grams per sq ft and effort, E, in man-min per 10^3 or 10^4 sq ft, are shown in Figs. 4.1.4 through 4.1.9. The actual data points, including one standard deviation are shown for each test. Derived values of $3K_o$, M_o^* and α are presented in Table 4.2.

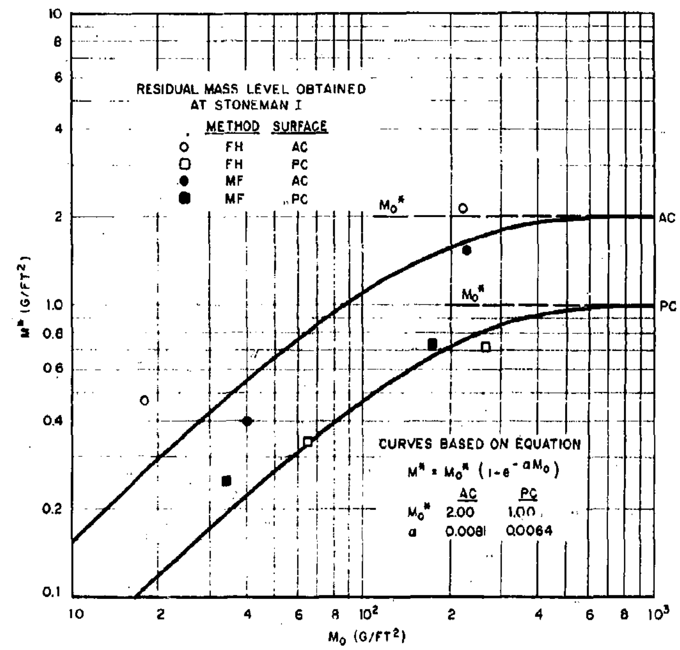

Fig. 4.1.1 Variation in M* With Increased Initial Mass M_o - Paved Area

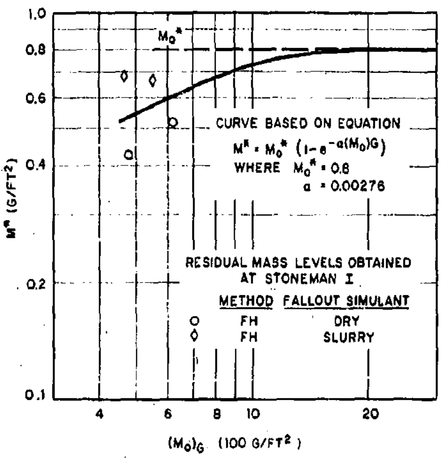

Fig. 4.1.2 Variation of M* With Initial Mass Loading Plus Loose Gravel $(M_o)_g$, Tar and Gravel Roofing

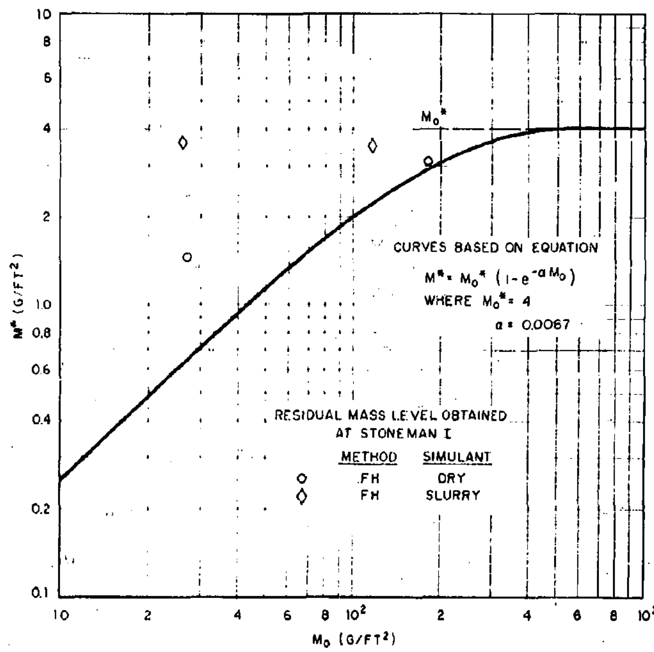

Fig. 4 1.3 Variation in M* With Initial Mass M_o - Composition Shingle Roofing

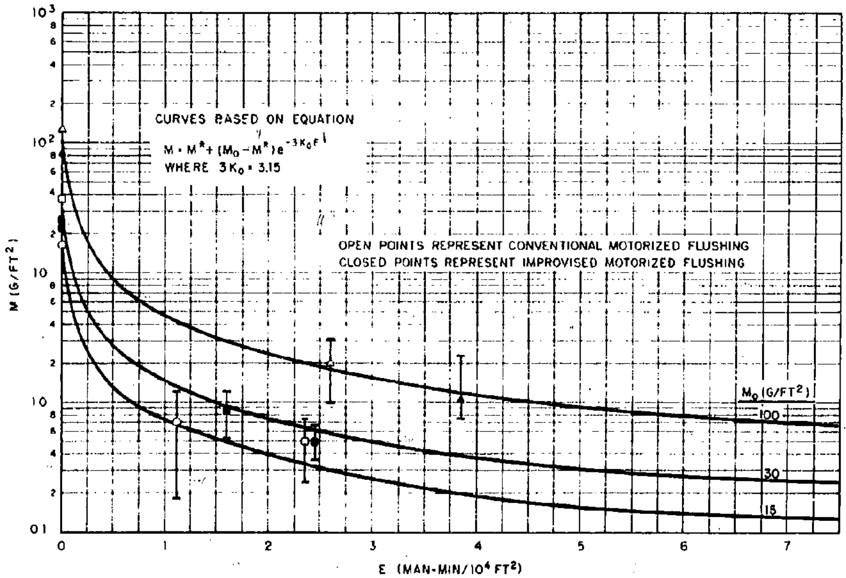

Fig. 4.1.4 Decontamination Effectiveness of Conventional or Improvised Motorized Flushing - Portland Cement Concrete

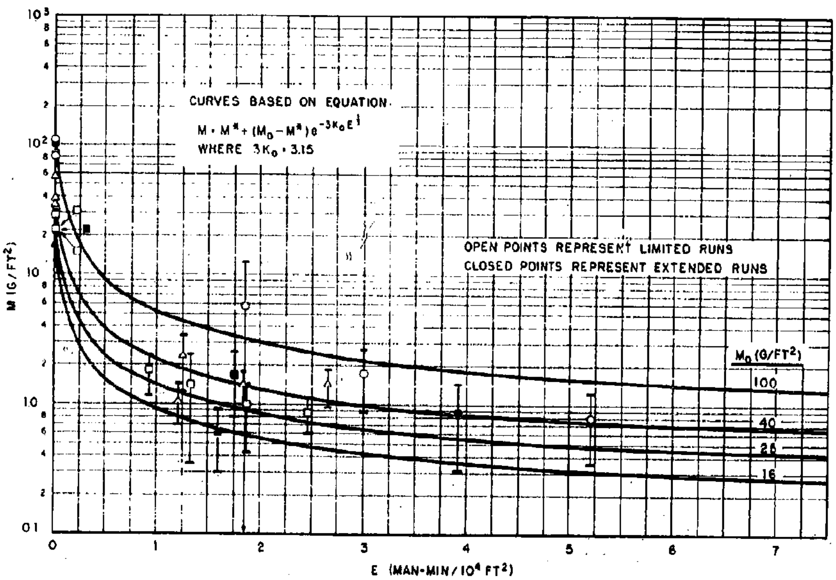

Fig. 4.1.5 Decontamination Effectiveness of Conventional Motorized Flushing - Asphaltic Concrete

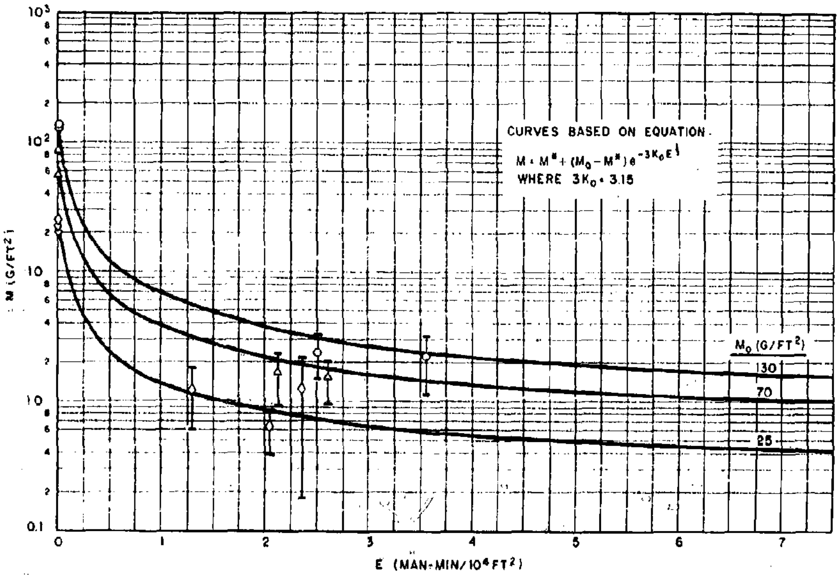

Fig. 4.1.6 Decontamination Effectiveness of Improvised Motorized Flushing - Asphaltic Concrete

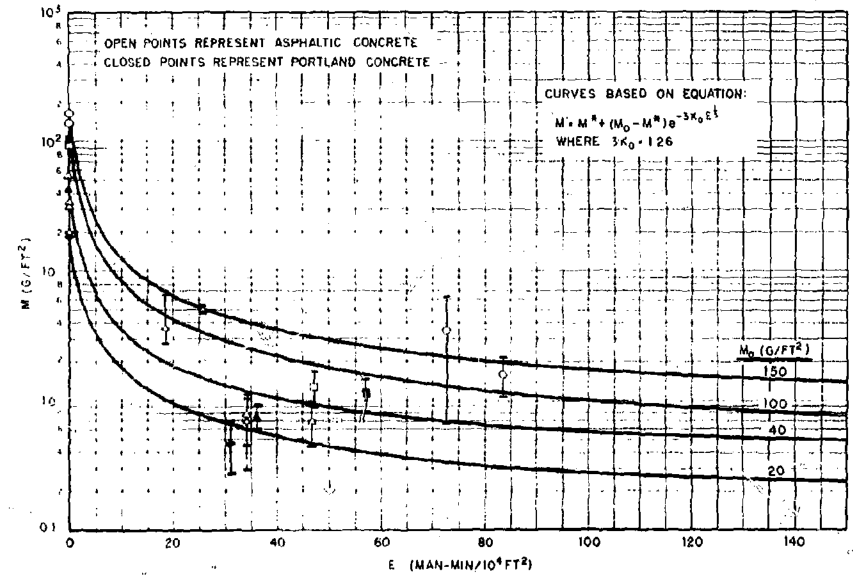

Fig. 4.1.7 Decontamination Effectiveness of Firehosing - Asphaltic or Portland Cement Concrete

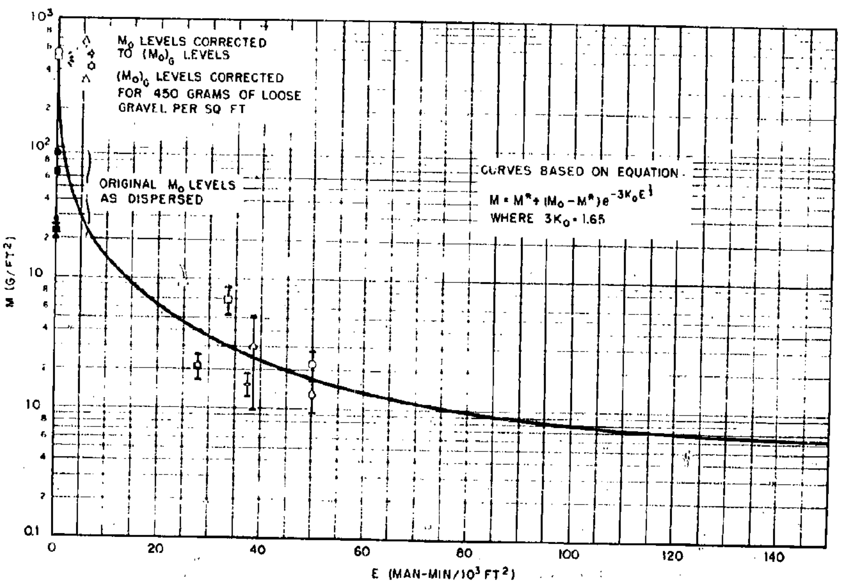

Fig. 4.1.8 Decontamination Effectiveness of Fan Nozzle Firehosing on Tar and Gravel Roofing

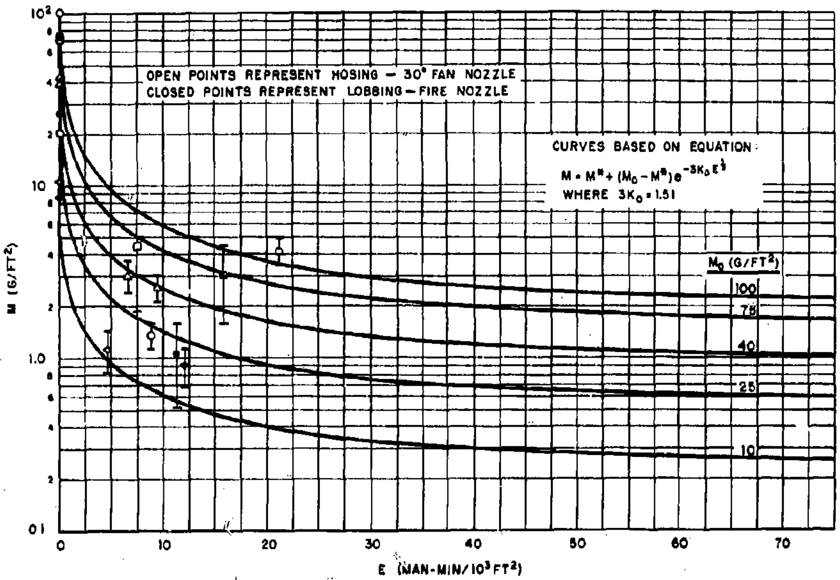

Fig. 4.1.9 Decontamination Effectiveness of Both Direct Hosing With Fan Nozzle and Lobbing With Firehosing Nozzle Techniques on Composition Shingles

TABLE 4.2

Derived Values of $3K_o$, M_o^* and α

Test No.	Method	Surface	$3K_o$	M_o^*	α
R1 to R6	Firehosing	Tar and Gravel	1.65	0.8	0.00235
R7 to R12	Firehosing	Comp. Shingles	1.51	4.0	0.0067
R13 to R15	Lobbing	Comp. Shingles	1.51	4.0	0.0067
A1 to A9	CMF	Asphalt	3.15	2.0	0.0081
A15 to A20	IMF	Asphalt	3.15	2.0	0.0081
A10 to A12	CMF	Concrete	3.15	1.0	0.0064
A21 to A23	IMF	Concrete	3.15	1.0	0.0064
A13,14 & 40	CMF	Asphalt	3.15	2.0	0.0081
A24 to A29	Firehosing	Asphalt	1.26	2.0	0.0081
A30 to A32	Firehosing	Concrete	1.26	1.0	0.0064

In attempting to fit the appropriate equations to the M vs E plots a number of adverse factors arose which permitted only the roughest of correlations, for example:

(1) The standard deviations of many of the data points are large, due to the various sources of error discussed in section 4.6.

(2) Because of the inability to restrict simulant dispersal to the three nominal mass levels (10, 30 and 100 g/ft^2), there were seldom more than two data points per curve.

(3) The range of efforts and initial mass levels covered was too narrow to confirm the equated shape of the curves.

4.1.1 Pavements

Plots of the motorized flushing data are contained in Figs. 4.1.4, 4.1.5 and 4.1.6. The curves are fitted to the data points in accordance with Eq. 4.8. The best correlation between the equated curves and the test points is noted on portland cement concrete. For asphaltic concrete, the fit of the curves to the plotted values is about the same for conventional flushing and improvised flushing. In either case the points are, for the most part, contained within a band whose boundaries are defined by the two outermost curves.

Figure 4.1.7 shows the correlation of the decontamination Eq. 4.8 with the firehosing data on portland cement concrete and asphaltic concrete, respectively. For either surface, the points fall reasonably close to the curves, except where effort is less than 25 man-min/ $10^4 ft^2$. The correlation is probably not as good as that shown by the motorized flushing.

4.1.2 Roofs

In the decontamination of tar and gravel roofing, most of the effort is expended in removing the loose gravel. For this reason the initial mass loadings for fitting the equation to the data were increased by 450 g/ft^2, which is the amount of loose gravel estimated to have been present prior to removal. The effect of this adjustment upon the curve of the decontamination equation is shown in Fig. 4.1.8. Although the data are slightly scattered, the test points are reasonably well centered about a curve equated to a corrected mass level of 500 g/ft^2. This indicates that for the original mass loadings of simulant dispersed in these tests, the amount of loose gravel was controlling. It would therefore seem advisable to remove this loose gravel before fallout arrival in order to reduce the recovery effort.

It should be noted from the family of curves in Fig. 4.1.9 that, within the limits of the test data, it is not possible to detect any difference in the decontamination effectiveness of direct firehosing with the fan nozzle or the lobbing with a firehose nozzle on composition shingles.

4.2 COMPARISON OF DECONTAMINATION RESULTS WITH RESPECT TO METHODS AND SURFACES

4.2.1 Pavements

Figure 4.2.1 indicates the relative effectiveness of pavement decontamination with a typical set of performance curves normalized at a common mass loading of 100 g/ft^2. It is immediately apparent from the slopes of the curves that motorized flushing is a more efficient removal method than firehosing, regardless of the type of pavement. Where firehosing requires an effort in excess of 75 man-min/10^4 ft^2 to reach the minimum residual mass level, M*, the motorized methods very nearly approach M* at the applied effort of only about 20 man-min/10^4 ft^2. Beyond this point the relatively flat slope of the motorized flushing curves indicates that a continued expenditure of effort would not reduce the levels very much.

The true advantage of motorized flushing over firehosing may not be as great as demonstrated in Fig. 4.2.1, because of the greater distance over which firehosing was required to push the fallout simulant. In this method, had the material been washed across the test strips (as in motorized flushing) instead of along their total length, the curves for firehosing undoubtedly would have been steeper. However, such a manual method, although more flexible, can hardly hope to develop the speed and, hence, the reduced effort characterized by mechanized flushing.

From the effectiveness curves presented in Section 4.1, no significant distinction can be made between the decontamination performances of conventional and improvised flushing. Thus the motorized flushing curves in Fig. 4.2.1 are for both methods. Accordingly, it is concluded that an improvised flusher system is a feasible method that is competitive with a conventional street flusher.

The lower curve in Fig. 4.2.1 demonstrates that for motorized flushing portland cement concrete was more readily cleaned than asphaltic concrete. This difference in decontamination is not detectable until a certain minimum effort has been invested. In the case of firehosing little difference in removal effectiveness could be detected due to differences in type of surface.

The improved effectiveness experienced during the motorized flushing of the portland cement concrete areas was not surprising, since they were in a better state of repair than the asphaltic concrete test areas. The portland cement concrete surfaces exhibited a relatively smooth rotary-trowelled finish, form lines were infrequent, cracks were practically non-existent, and the slopes were all uniform though almost flat. On the other hand the asphaltic concrete surfaces were inherently rougher in texture, they contained depressions and swells, and they exhibited reversals in the cross slopes. All these factors are, of course, detrimental to the cleaning action of fluid streams, especially those that are mechanized and have a fixed orientation with respect to the vehicle.

4.2.2 Special Tests on Pavements

Tests A13 and A14 were conducted with the conventional flusher on a 500 ft long, hilly roadway. The average grade over the central 200 ft was 5.8 percent and that of the two end portions (approximately 150 ft each) was 0.3 percent. Since the road was crowned, the first two passes were made from the center line, one downhill and one uphill to avoid having to change the position of the nozzles. Two more passes, one along each curb completed a test run.

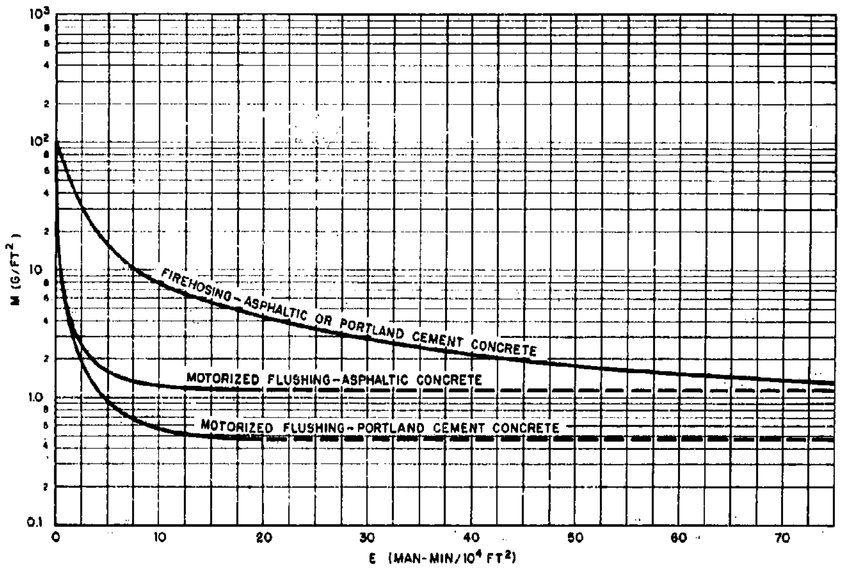

Fig. 4.2.1 Comparative Effectiveness of Motorized Flushing and Firehosing on Pavement

These runs demonstrated that grades of 6 percent or less do appreciably change the decontamination performance relative to that found for the 150 ft, relatively level, test strips. There were indications that a longer and/or steeper grade would reduce flusher speed appreciably on an uphill pull, especially when fully loaded with water. This, of course, would increase the effort and the consumption of water.

Test A40 was performed as a combined sweeper-flusher operation on a straight, level roadway having a relatively flat crown. The results are shown in Table 3.1. A conventional street sweeper removed the bulk of the contaminant, leaving an average level of 23 g/ft^2 for the flusher. Based on tests for comparable mass loadings (refer to Table 3.1 and Fig. 4.1.5) the flusher did not provide the expected degree of effectiveness. For the effort expended, the final level should have been nearer 1 g/ft^2 rather than 1.68 g/ft^2. Even so, the latter value was less than would be expected from a sweeping operation alone (see Volume III of the STONEMAN II report series). Assuming that Eq. 4.8 and the appropriate constants apply, a flushing operation alone could presumably have reduced the original mass level of 141 g/ft^2 to 1.68 g/ft^2 for an effort no greater than the total expended in the combined operation (7 man-min/10^4 ft^2).

4.2.3 Roofs

In order to evaluate the relative decontamination effectiveness of wet methods on roofs, M vs E curves were drawn for two initial mass levels (25 and 100 g/ft^2) as shown in Figs. 4.2.2 and 4.2.3. Equation 4.8 was used to obtain these curves for tar and gravel and composition shingles, respectively.

As mentioned before, for a given initial mass loading, a single curve represents either the fan nozzle or the fire nozzle as employed on composition shingles. This is surprising since one would normally expect the direct application at roof level of a high pressure stream, as typified by the fan nozzle, to provide greater removal effectiveness than indirect lobbing of a low pressure fire stream from ground level. Such factors as stream direction relative to the roof's slope, nozzle pressure and stream impact were all to the advantage of the fan nozzle. Roof slopes were the same in all cases. Therefore, the competitive performance of the lobbing procedure must have been due, in part, to a superior stream pattern. Increased thickness in the water film flowing down the roof may also have been a contributing factor. This increase in film thickness was probably equal to the increase in stream flow rate; namely, 20 percent (72 gpm vs. 60 gpm).

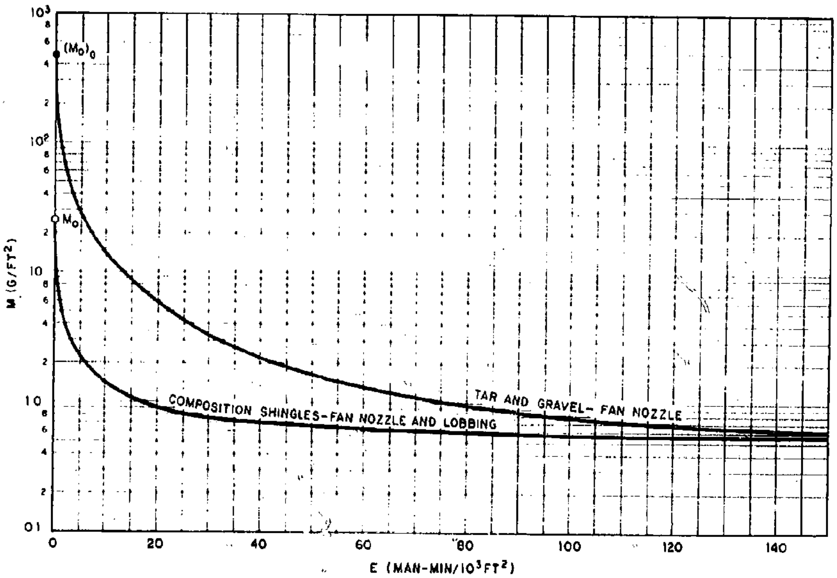

Fig. 4.2.2 Comparative Effectiveness of Decontamination Methods on Roofs for an M_0 of 25 g/ft^2

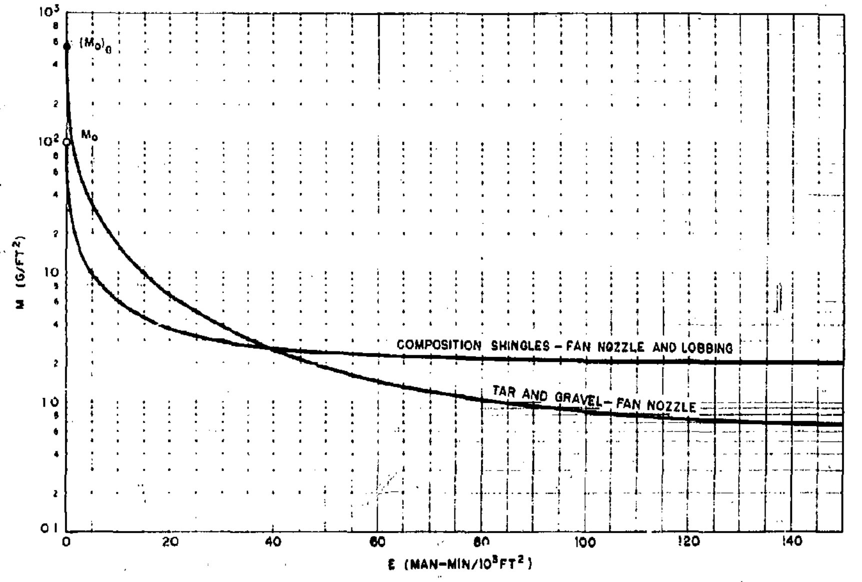

Fig. 4.2.3 Comparative Effectiveness of Decontamination Methods on Roofs for an M_o of 100 g/ft^2

The 30^{o} fan nozzle was used on both types of roofing surfaces tested. Besides differences in the surface materials, other differences in the test conditions were: the tar and gravel roofs were almost flat, while the composition shingle roofs had a slope of 1/2.5; in the decontamination of tar and gravel roofs the gravel had been removed along with the contaminant, resulting in a considerable effort independent of the initial mass level. Mainly because of the latter, it is reasonable that composition shingles should clean more readily for a limited expenditure of effort, say not more than 40 man-min/10^3ft^2.

However, the curves of Fig. 4.2.3 for higher initial mass loadings (100 g/ft^2) indicate that for efforts greater than 40 man-min/ 10^3ft^2, composition shingles do not decontaminate to as low a level as tar and gravel roofing. This occurs in spite of the fact that the curves for tar and gravel are practically the same for the two mass loadings represented.

4.3 EFFECT OF INITIAL MASS LEVEL AND EFFORT ON RESIDUAL MASS LEVEL

The relationships expressed in Equations 4.1 and 4.8 were derived using the hypothesis that the residual mass level is a function of the initial mass level and effort expended. The two equations can be combined giving

$$M = M_o^* \,(1-e^{-\alpha M_o}) + \left[M_o - M_o^* \,(1-e^{-\alpha M_o})\right] e^{-3K_oE^{1/3}}$$

Figures 4.3.1 to 4.3.4 show graphically the stated relationships for each of the surface-method combinations evaluated.

These curves can be utilized to determine what level of effort is needed to produce a required residual mass level for a range of expected mass loadings.

4.4 OPERATIONAL CHARACTERISTICS OF DECONTAMINATION EQUIPMENT

Although the equipment used in these tests is, for the most part, comprised of standard components, the performances required in the removal of dry fallout are not necessarily the same as those for which the equipment was originally designed. In seeking to achieve a satisfactory balance among such factors as removal effectiveness, effort,

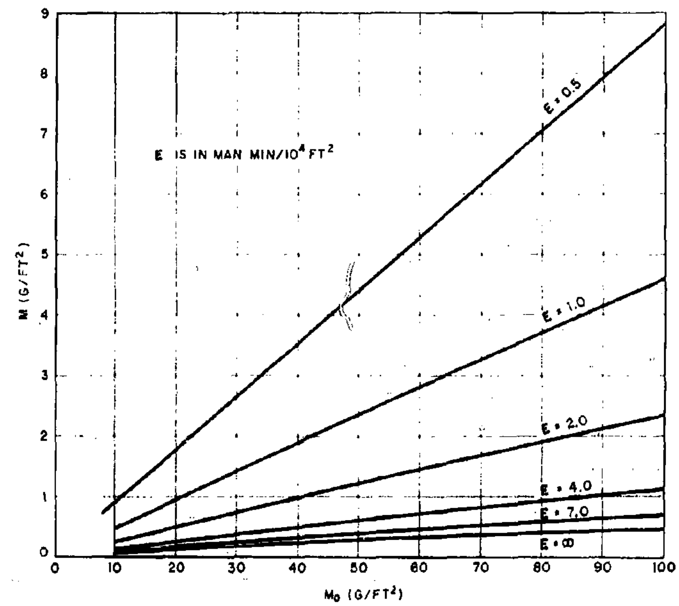

Fig. 4.3.1 Residual Mass as a Function of Initial Mass Loading - Conventional or Improvised Motorized Flushing of Portland Cement Concrete

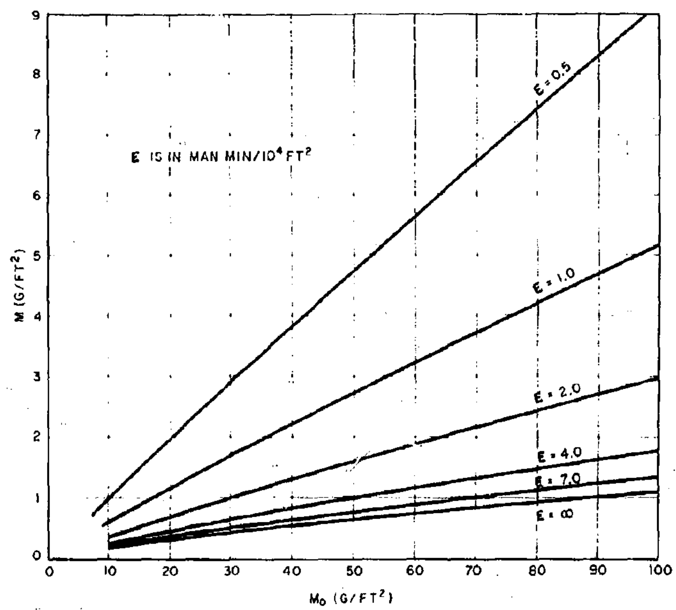

Fig. 4.3.2 Residual Mass as a Function of Initial Mass Loading - Conventional or Improvised Motorized Flushing of Asphaltic Concrete

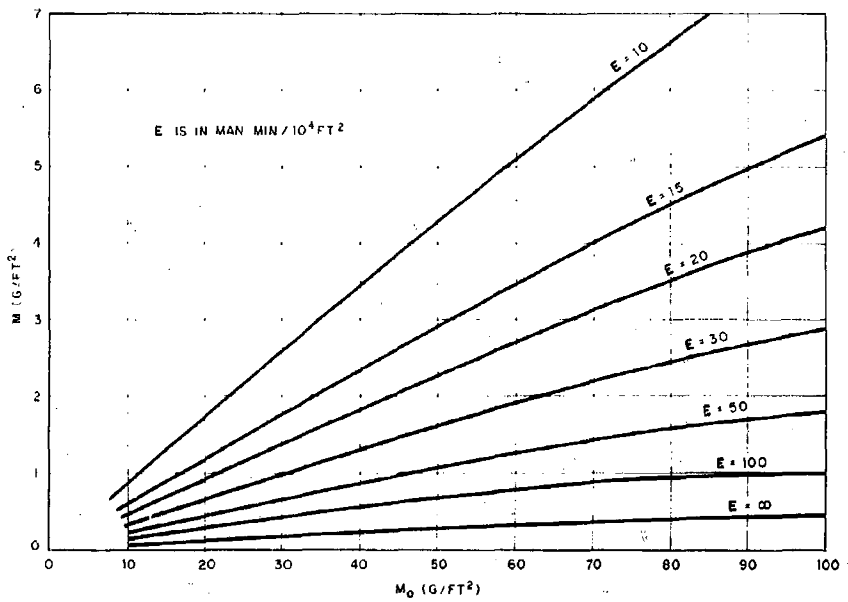

Fig. 4.3.3 Residual Mass as a Function of Initial Mass Loading - Firehosing Asphaltic or Portland Cement Concrete

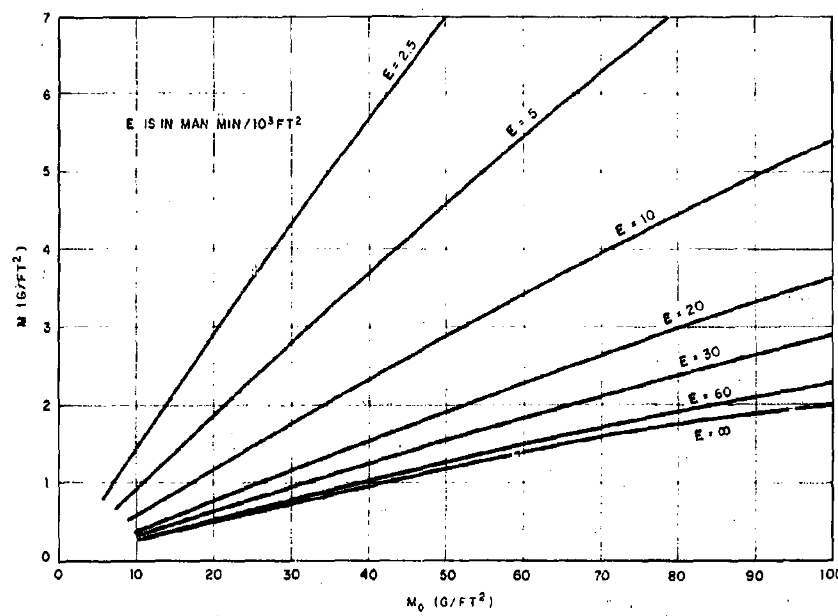

Fig. 4.3.4 Residual Mass as a Function of Initial Mass Loading - Fan Nozzle or Lobbing Techniques on Composition Shingles

and water consumption the mode of operation influences the operating characteristics of the equipment. These and other controlling factors are discussed below.

4.4.1 Conventional Motorized Flushing

Conventional street flushers are normally employed to push debris from the middle of streets to the gutters where it can be picked up later by other means such as sweepers. In the removal of fallout material, flushers are expected to have the capability to clean gutters also. It was found during the tests that this could only be accomplished by straddling the curb, otherwise large amounts of contaminant would be splattered on sidewalks, yards and building fronts. Because of the many obstructions commonly located along curbs, flushers should be outfitted with special nozzles which can be swung out over the gutters.

The curbless roads so prevalent in military installation and open highways are best suited to flusher operations. Here the motorized flusher can take full advantage of its high pressure system to throw the fallout particles free of the roadway and beyond the shoulders. When using this technique, the contaminant may settle in the drain ditches adjacent to the roadway, rather than passing into the sewer system, and prevent the immediate attainment of the desired decontamination effectiveness.

The effort required to remove heavier mass loadings (approaching 200 g/ft^2) by motorized flushing techniques is known to be quite high. If the bulk of material is first removed by a sweeping operation, flushing can then be utilized to best advantage to obtain a low residual level. Test A-40 showed that such a combination was feasible. Although not necessarily more effective than flushing itself, the fact remains that sweeping reduces the total effort ultimately required of flushing to reach a given residual mass level. In view of the far greater availability of street sweepers, a combined operation would be advantageous.

The basic design and arrangement of flusher nozzles is not particularly adaptable to decontamination work. Some criticisms are:

1. The broad stream angle, which is greater than 90 degrees, doesn't permit the desired control over the direction in which the contaminant is trajected.
2. The stream pattern is of nonuniform thickness and contributes to uneven removal.
3. The nozzle arrangement is such that it is extremely awkward to adjust and match the water jets to prevent streaking.

4. When the above condition is satisfied only one set of wheels are provided a clean path to run in. The other set must track through fallout material.

4.4.2 Improvised Motorized Flushing

The improvised flushing overcomes the first three objections cited above. In addition, the flusher bar tested can be attached to any portable tank equipped with a prime mover and a defense pump to convert it into an effective flusher. The performance of the improvised nozzle system in these tests indicate the feasibility of such an arrangement.

Improvised flushing systems offer a wide range of possibilities since there is very little size restriction in construction of the nozzle bar. Small highly maneuverable jeep drawn systems might be designed for sidewalks and ramps. Extra large capacity systems, consisting of a series of tank trailers drawn by a tractor, could be used to decontaminate long expanses of highway and important access roads.

The main objective of improvised flushers, however, would be to supplement the relatively small number of conventional flushers presently available.

4.4.3 Firehosing

Firehosing as used in the removal of fallout is an adaptation of readily available equipment for furnishing water at high pressures to move particles along the surface (rather than to extinguish fires.) Experience has shown that, contrary to fire fighting practice, where 2-1/2 and 3 in. hoses are used, 1-1/2 in. hoses and nozzles give the best performance. The manpower required to properly direct 2-1/2 in. nozzles and oppose their thrust is prohibitive. The 2-1/2 in. hose is used instead to supply water for two 1-1/2 in. nozzles as employed in the paved area tests. The use of a jeep or similar vehicle to drag several hundred feet of such large hose as the cleaning operation progresses, cuts the manpower requirements in half. It also serves to stabilize the operation into an uninterrupted removal process by freeing the nozzle men from hose tending duties.

Working with firehoses and opposing 40 pounds of nozzle thrust on pitched roofs can be hazardous. Pressure surges, nozzle whip, slippery footing and worker fatigue, taken singly or together, can result in serious casualties. For this reason, lobbing streams from ground level onto roofs with steep slopes is a more desirable technique; and, for most prominently sloped roofs, it is probably just as effective as direct hosing at roof level (see Fig. 4.1.9).

Tar and gravel roofs do not lend themselves to lobbing techniques due to the large amount of gravel that must be removed and the low roof pitch. Because of their relatively flat slopes, however, decontamination operations with high pressure streams can be carried out in comparative safety.

Before initiating any wet decontamination procedures on roofs, all electrical power to buildings should be cut. Care must be exercised to not inadvertently play water streams onto nearby power lines and transformers which may still be activated.

The advantage of fan shaped streams over standard fire streams was not definitely established (as they were not tested under the same conditions). The general improvement in the overall technique employed on tar and gravel may have been more responsible for the increased performance than the fan nozzle.

4.5 SOURCES OF ERROR

Error in the results came from two major areas, namely the determination of the mass level on the surface and the performance of the decontamination equipment. The sources of error in the performance data are quite limited and fairly unimportant. Possible sources of error include: total time consumed; equipment variability such as pump, and hence nozzle pressures; and operator variability, due primarily to increasing experience.

The main sources of mass level error include the following areas: synthetic fallout composition, instrumentation, distribution and redistribution of the synthetic fallout, and surface condition. Considerable variation in composition existed between individual batches of the synthetic fallout material (see Vol. I of this series of reports for further details). Although there is presently insufficient information available to determine the importance of these variations upon the results, it has been assumed to be relatively unimportant when comparing the various methods. The primary source of instrumentation error was from the mobile shielded detector; it is estimated that timing variations and change of response in the crystal caused an error of approximately 12.5 %. The 4-pi gamma ionization chamber and the large sample counter, being laboratory instruments, have an inherent error of less than 2 %. Redistribution by wind of the synthetic fallout during or after spreading was the largest unknown factor in the data. Even a low wind blowing during the spreading operation could fractionate the synthetic fallout by carrying away the fine particles while allowing coarser material to settle on the surface.

This fractionation, although occurring before surface readings were taken with the mobile shielded detector, could cause a variation in the specific activity of the contaminant, producing anomalous readings. The most important wind effects, however, were those produced by a moderately strong wind blowing across the test strip after the initial reading (I_r) had been taken but prior to decontamination. In such cases, the calculated initial mass level could be in error by as much as a factor of two. The two major sources of errors, wind effects and instrument error, are largely cancelled out by using the calibration factor k (see Appendix C). The variation in the individual readings, expressed as one standard deviation, are shown on Figs. 4.1.4 through 4.1.9.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Two parameters, derived from the test data, and used for the comparison of methods, were K_o which is an expression of rate of removal and M_o^* which is an expression for the ultimate level obtainable at very high effort levels. The derived values of $3K_o$ and M_o^* are shown below.

Method-Surface	$3K_o$	M_o^*
Conventional Flushing - Asphaltic Concrete	3.15	2.00
Conventional Flushing - Portland Concrete	3.15	1.00
Improvised Flushing - Asphaltic Concrete	3.15	2.00
Improvised Flushing - Portland Concrete	3.15	1.00
Firehosing - Asphaltic Concrete	1.26	2.00
Firehosing - Portland Concrete	1.26	1.00
Firehosing - Tar and Gravel Roofing	1.65	0.80
Firehosing - Composition Shingles	1.51	4.00
Lobbing - Composition Shingles	1.51	4.00

The most efficient method would be one which has the highest K_o value and lowest M_o^* value.

The wet decontamination methods tested were found to be effective in removing all the initial mass loadings used in the tests on all the surfaces. For any given method/surface combination, the removal effectiveness was observed to be a function of the initial mass loading and the effort expended. In case of tar and gravel roofing, the amount of loose gravel must be taken into account.

The performance of motorized flushing was superior to that of firehosing for both types of pavement.

Portland cement concrete was more readily decontaminated by motorized flushing than asphaltic concrete.

An improvised flusher system was found to be a feasible method and also found to be competitive with a conventional type flusher, insofar as decontamination performance is concerned.

Streets having a prominent grade (not more than 6 percent) do not impair the operation nor the removal effectiveness of motorized flushing techniques.

The fan nozzle represents an adequate tool for the decontamination of roofs, including tar and gravel and composition shingles.

Lobbing of firestreams from ground level is competitive with direct hosing at roof level, providing roof surfaces are reasonably smooth and roof slopes furnish ample drainage.

5.2 RECOMMENDATIONS

Because of the difficulty in evaluating the exactness of fit of the decontamination equation with the test data it will be necessary in future tests to determine the respective values of M^*, M^*_o, α and K_ω over a broader range of effort and initial mass loadings. The introduction of more closely controlled decontamination rates and other related parameters in future tests should further improve the present theoretical equations or provide information that will lead to the development of a more exact theory. This would provide more reliable methods of interpolating and extrapolating the data to other conditions of interest and reduce the requirement for costly and extensive experimentation.

As a means of improving the performance of wet removal methods, continued studies should be made of nozzle design and arrangement for both mechanized and manual techniques. This could be an extension of the type of investigations described in Appendix A and would measure the importance of stream pattern, nozzle attitude, stream energy etc. with respect to removal effectiveness and effort.

More complete testing of the performance of combined decontamination procedures (dry and wet) is recommended, in order to fully exploit the best features of each.

The possibilities of lobbing techniques should be explored in order to define the limits imposed by roof slope and surface roughness.

A means for controlling the gravel removed from tar and gravel roofs should be developed to minimize or eliminate the problem of ultimately having to remove this same gravel from building surroundings.

The removal of loose gravel prior to the arrival of fallout should be considered as a means for reducing the recovery effort expended on tar and gravel roofs.

Approved by:

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For the Scientific Director

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APPENDIX A

PRELIMINARY STUDIES

A preliminary experiment was conducted on a complete assortment of nozzles to observe the behavior of jet impact as a function of nozzle pressure and range. The tests consisted of directing the nozzled streams against a flat plate fixed to a weighted pendulum. Any deflection noted in this apparatus was directly proportional to the impact forces acting on it.

Tables A.1, A.2 and A.3 show the test results on three types of nozzles; fire, street flusher and specially manifolded nozzles, respectively. As expected, the deflection (and hence the impact) increased with the pressure for all nozzles tested regardless of type. Except for the street flusher nozzles, however, the influence of range* on deflection (impact) was negligible. Table A.1 indicates that, for any fire nozzle under a given pressure, the deflection was essentially constant over ranges of 1 to 8 feet. For the specially manifolded nozzles covered in Table A.3 deflections were again almost constant at ranges of 1/2 to 4 feet. Greater ranges were of no interest, since these nozzles were designed to be used relatively close to surfaces.

As shown in Table A.2, impact tests of conventional flusher nozzles were performed at three nominal orifice settings. Because of increasing difficulties with the pressure system it was impossible to duplicate flow rates of certain runs, particularly at the 1/8 inch setting.

At a pressure of 40 psi and a setting of 1/16 inch, the deflections appear inversely proportional to the range. Loss of impact was about 9 percent as the range increased from 1 to 3 feet. Where a 3/64 inch setting was employed, the deflections were unaffected by the slight changes in range at the given test pressures (40 and 50 psi). A break up in stream pattern was observed later during field runs at higher pressures; hence, it is possible, that for this specific nozzle design, 3/64 inch is a critical setting. It was therefore decided to use the 1/16 inch setting during actual street flusher tests as it used the least volume of water without permitting separation of the jet stream.

*The distance between nozzle and impact plate at zero deflection.

TABLE A.1

Impact Tests of Fire Nozzles

Nozzle Type	Orifice Diam. (in.)	Press (psi)	Flow (gpm)	Range (ft)	Deflection (in.)
1-1/2 in. Fog Nozzle	5/8	40	68	8	3-1/2
		80	96	8	7-1/4
		125	124	8	11-3/4
1-1/2 in. Fire Nozzle	5/8	40	70	8	4-1/2
			72	4	4-1/8
			72	1	4
		80	100	8	7-3/4
			100	4	8
			102	1	8
		125	126	8	11-3/4
			126	4	11-3/4
			126	1	11
1-1/2 in. Forester	1/2	50	50	8	3-1/2
			52	4	3-3/8
			52	1	3-1/8
		100	70	8	6-1/2
			72	4	6-3/4
			74	1	6-3/8
		175	96	8	11-1/2
			94	4	11
			98	1	11
1-1/2 in. Forester	7/16	75	46	8	3-3/4
			50	4	3-5/8
			48	1	3-7/8
		150	62	8	7
			64	4	6-7/8
			67	1	7-1/8
		200	72	8	9
			74	4	9-1/4
			74	1	9-1/8
1-1/2 in. Forester	3/8	75	36	8	3
			38	4	3-1/8
			39	1	2-3/4

TABLE A.1 (Contd)

Impact Tests of Fire Nozzles

Nozzle Type	Orifice Diam. (in.)	Press (psi)	Flow (gpm)	Range (ft)	Deflection (in.)
		150	50	8	5-3/4
			52	4	5-5/8
			51	1	5-3/4
		200	56	8	7-1/4
			60	4	7-3/8
			59	1	7-1/8
1-1/2 in. Forester	5/16	75	24	8	2
			26	4	1-3/4
			25	1	1-3/4
		150	34	8	4
			34	4	3-3/4
			33	1	3-7/8
		200	38	8	4-3/4
			40	4	5
			38	1	5-1/8
Curve Tip (Devilbis)	5/16	75	21	8	1-1/2
			21	4	1-5/8
			22	1	1-1/2
		150	30	8	3-1/4
			30	4	3-3/8
			30	1	3-1/2
		200	34	8	4-1/4
			37	4	4-1/2
			34	1	4-3/4
1 in. Lance - Conical Tip	3/8	50	26	6	1-5/8
			26	1	1-1/2
		100	34	6	3
			34	1	3
		150	44	6	4-1/2
			44	1	4-3/8
		200	50	6	5-7/8
			50	1	5-3/4

Continued

TABLE A.1 (Contd)

Impact Tests of Fire Nozzles

Nozzle Type	Orifice Diam. (in.)	Press (psi)	Flow (gpm)	Range (ft)	Deflection (in.)
Curve Tip	3/8	50	22	6	1-1/4
			22	1	1-1/4
		100	30	6	2-1/2
			30	1	2-5/8
		150	38	6	3-7/8
			38	1	3-7/8
		200	44	6	5
			44	1	5

TABLE A.2

Impact Test of Conventional Flusher Nozzles

Orifice Dimensions* (in. X in.)	Press (psi)	Flow (gpm)	Range (ft)	Deflection (in.)
8-1/2 X 1/8	10	140	2	38
	15	180	2	63
	20	220	2	87
8-1/2 X 1/16	25	130	2	48
	30	140	2	63
	40	180	3	83
		180	2	90
		180	1	91
8-1/2 X 3/64	30	80	2	35
	40	90	2	49
		90	1	49
	50	100	3	62
		100	2	61

*Fractions shown for minor orifice dimension are approximate.

TABLE A.3

Impact Test of Specially Manifolded Nozzles

Nozzle Designation*	No. of Nozzles	Orifice Diam. (in.)	Press (psi)	Flow (gpm)	Range (ft)	Deflctn (in.)
U1550	6	11/64	50	32	1/2	1-3/4
				32	1	1-3/4
				32	4	1-3/4
			100	46	1/2	3-1/2
				46	1	3-1/2
				46	4	3-1/2
			150	56		5-1/2
				54	do	5-1/4
				54		5-1/4
			200	64		7-1/8
				64	do	7
				64		6-7/8
U1570	4	13/64	50	30		1-1/2
				30	do	1-1/2
				30		1-5/8
			100	42		3-1/4
				42	do	3-1/4
				42		3-1/8
			150	50		5
				50	do	4-7/8
				50		4-7/8
			200	58		6-3/8
				58	do	6-3/8
				58		6-1/4
U0070	4	13/64	50	26		1-1/2
				26	do	1-1/2
				26		1-1/2

Continued

TABLE A.3 (Contd)

Impact Test of Specially Manifolded Nozzles

Nozzle Designation*	No. of Nozzles	Orifice Diam. (in.)	Press (psi)	Flow (gpm)	Range (ft)	Deflctn (in.)
			100	34		2-7/8
				34	do	2-3/4
				34		2-3/4
			150	44		4-3/8
				44	do	4-1/4
				44		4-1/8
			200	50		5-3/4
				50	do	5-5/8
				50		5-1/2

*Model numbers of Spraying Systems Co.

Improvised Jeep Flusher Tests

Because street flusher was being repaired at the time, it was necessary to carry out interim test runs with an improvised flusher system. This system consisted of a jeep drawn crash trailer, with sets of suitably manifolded nozzles attached to the bumper of the jeep. A tank, with high pressure pump, on the trailer supplied water through hoses to the nozzle manifold. The latter was made up of 6 nozzles spaced on 5-5/8 inch centers along a 1-1/4 inch pipe. Fan shaped streams from each nozzle combined to form a continuous flat sheet of water about 36 inches wide.

Cleaning passes were made at controlled speeds over asphalt paved areas covered with approximately 100 gms of nonradioactive simulated fallout soil per square foot. The attack angle α (between the stream and the pavement) and the azimuth angle β (between the stream and the direction of jeep travel) were varied to determine the optimum nozzle attitude. A constant range of 24 inches was maintained between the nozzle tips and the paved surface. Four different sets of nozzles were tested. The cleaning rate was paced by the visual removal of the fallout simulant.

Table A.4 contains the jeep flusher system performance figures for those runs which appeared to give an estimated average removal effectiveness of 95 percent. It is of minor importance to note here that the best performance from the standpoint of rate of removal and water consumption was obtained with the U1550 and U1520 nozzles. The really significant findings concern the behavior of nozzle arrangements belonging to this general design.

Before discussing the findings it is necessary to explain two of the column headings - the first being the one entitled Economy Ratio (ρ). Since it is desirable to achieve a high rate of removal with a low expenditure of water, the ratio of rate over unit consumption would seem to indicate relative cost of the various test runs. A high value of ρ means savings in water and time (as well as dosage to recovery teams). It should be noted that ρ has the rather unusual dimensions of $ft^4/gal/min$. Another value was also computed and entered in the column headed Unit Energy. This quantity is the stream energy per unit area in ft lb/ft^2.

During the test runs it was observed that less streaking occurred and hence greater removal effectiveness resulted for attack angles of 30 and 45 degrees and an azimuth angle of 60 degrees. A study of Table A.4 discloses that the economy ratios were also greatest at these settings, ranging from 5 to 6.7.

TABLE A.4

Improvised Jeep Flusher Tests

Nozzle* Desig-nation	Orifice Diam. (in.)	Press (psi)	Flow (gpm)	Rate (ft^2/min)	Unit Consumption $\frac{gal}{1000\ ft^2}$	Econ Ratio (ρ)	Attack Angle (α^o)	Azimuth Angle (β^o)	Unit Energy (ft-lb/ft^2)
U1550	11/64	45	32	364	87	4.2	60	45	74
		45	32	385	88	4.4	45	45	75
		45	32	308	104	3.0	30	45	90
		45	32	333	96	3.5	15	45	83
		45	32	333	96	3.5	60	30	83
		45	32	333	96	3.5	45	30	83
		45	32	333	96	3.5	30	30	83
		45	32	400	80	5.0	30	60	69
		45	32	400	80	5.0	45	60	69
		45	32	400	80	5.0	60	60	69
U1520	7/64	85	17.5	322	54	6.0	45	60	88
		90	18	328	55	6.0	30	60	95
		90	18	308	59	5.2	30	45	100
		90	18	278	65	4.3	45	45	111
		90	18	350	52	6.7	45	60	89
U1540	5/32	54	27.5	278	99	2.8	45	60	100
U1530	9/64	65	23	270	85	3.2	45	60	106

*Model numbers of Spraying Systems Co.

Tests of Fire Streams

Tests were also conducted with a variety of hand held nozzles which provided three basic stream patterns; i.e., cylindrical, conical, and fan shaped. The test surface (pavement) the concentration of soil simulant (100 g/ft^2) and the required removal effectiveness (95) were the same as before. Cleaning passes were again made at visually controlled rates. By using a 500 gpm defense pump at the hydrant a wide selection of pressures were available. Standard 1-1/2 inch firehose was used with al... 'e nozzles tested.

Table A.5 gives the results for the cylindrical and conical stream patterns. A study of the tabulated values discloses that, wherever two or more runs were made with a given nozzle the rate always increased directly with the pressure. Curves of pressure p versus rate R are shown on the log-log plots of Figs. A.1 through A.4. With but one exception, these curves appear as straight lines having the same positive slope m equals 2. The general equation fitting these curves is

$$\ln p_2 - \ln p_1 = m\,(\ln R_2 - \ln R_2).$$

When p_1 equals 1, $\ln p_1$ is zero and $\ln R_1$ becomes a constant $\ln G$ and

$$\ln p_2 = \ln (R_2/G)^m$$

or

$$R = G' p^{1/m} \tag{A.1}$$

From a further examination of Table A.5 it can be seen that, with one exception,* the unit consumption remains fairly constant for a particular nozzle. This all points to the possibility of some correlation between the constant in equation A.1 and the constant behavior of the unit consumption. By definition,

$$\text{Unit Consumption } C_u = Q/R \text{ gal/ft}^2 \tag{A.2}$$

Since Q is for all practical purposes equal to orifice area "a" times $p^{1/2}$,

$$C_u = a\, p^{1/2}/R$$

or

$$R = \frac{a}{C_u}\; p^{1/2} \tag{A.3}$$

*The exception noted here and earlier involves the same group of data; namely, that obtained from testing the 1-1/2 inch suicide nozzle with a specially reammed 5/8 inch tip.

TABLE A.5

Tests of Handheld Fire Streams

Nozzle Type	Orifice Diam. (in.)	Range (ft)	Press. (psi)	Flow (gpm)	Rate (ft^2/min)	Unit Cnsmptn $\frac{gal}{1000\ ft^2}$	Econ. Ratio (ρ)
		Cylindrical Patterns					
1-1/2 in. suicide	5/8	6-8	38	70	260	269	0.97
			44	75	235	319	0.78
			65	90	285	315	0.91
			75	100	333	300	1.11
1-1/2 in. fog	5/8	6-8	75	98	333	295	1.13
			80	96	333	288	1.16
1-1/2 in. suicide	5/8	15	44	70	410	170	2.41
			50	80	490	163	3.00
			70	95	506	188	2.70
1-1/2 in. fog	5/8	10-12	36	68	370	184	2.00
		15	54	77	465	165	2.82
		20-30	70	90	500	180	2.78
1-1/2 in. Forester	1/2	12	58	55	285	194	1.47
		12-15	60	56	250	224	1.12
		20-30	96	71	385	186	2.07
		15-20	110	77	350	220	1.59
		15-20	120	80	385	240	1.60
1-1/2 in. Forester	7/16	20-25	70	46	285	161	1.77
		15-20	70	46	244	188	1.30
		20-30	100	54	333	162	2.06
		20-30	144	62	333	186	1.79
1 in. Lance (Strait Tip)	3/8	6-8	160	45	181	249	0.73
			180	47	150	313	0.48
1 in. Lance (Curve Tip)	3/8	6-8	160	39	215	181	1.19

Continued

TABLE A.5 (Contd)

Tests of Handheld Fire Streams

Nozzle Type	Orifice Diam. (in.)	Range (ft)	Press. (psi)	Flow (gpm)	Rate (ft^2/min)	Unit Cnsmptn $\frac{gal}{1000\ ft^2}$	Econ Ratio (ρ)
			Conical Patterns				
1-1/2 in. Reamed	5/8	10	34	66	470	140	3.36
			37	70	485	144	3.36
			46	77	610	126	4.83
			50	80	565	141	4.00
			66	92	900	102	8.82
			75	99	900	108	8.34
1-1/2 in. Reamed	1/2	6-8	46	48	320	150	2.13
			70	60	345	174	1.98
			100	72	510	141	3.61
1-1/2 in. Reamed	7/16	6-8	100	54	300	180	1.67
			135	62	355	175	2.03
			150	66	380	174	2.18
1-1/2 in. Reamed	3/8	6-8	115	46	276	167	1.65
			150	52	330	157	2.10
1-1/2 in. fog	3/8	15-20	90	42	307	137	2.47
1-1/2 in.	3/8	12-15	120	47	350	134	2.61
		12	140	50	390	128	3.05
		10-12	160	53	417	127	3.28
		15	200	58	460	126	3.65
			Large Scale Stoneman II Dress Rehearsals				
1-1/2 in. suicide	5/8	15-20	68	93	530	175	3.03
			80	100	650	154	4.22
1-1/2 in. Reamed	5/8	10	70	95	860	110	7.82
			75	98	790	124	7.02
1-1/2 in. Forester	1/2	15-20	110	78	460	169	2.72

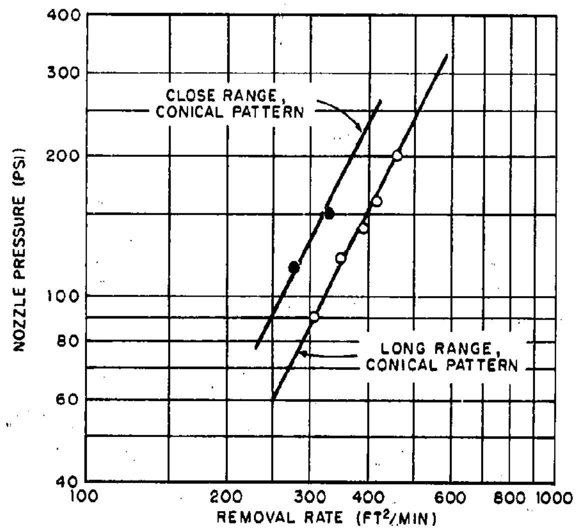


Fig. A.1 **Performance Curves of 3/8 inch Forester Nozzles**

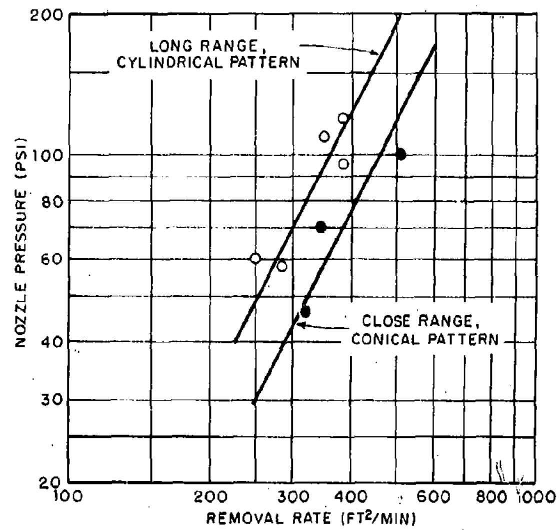


Fig. A.2 Performance Curves for 1/2 inch Forester Nozzles

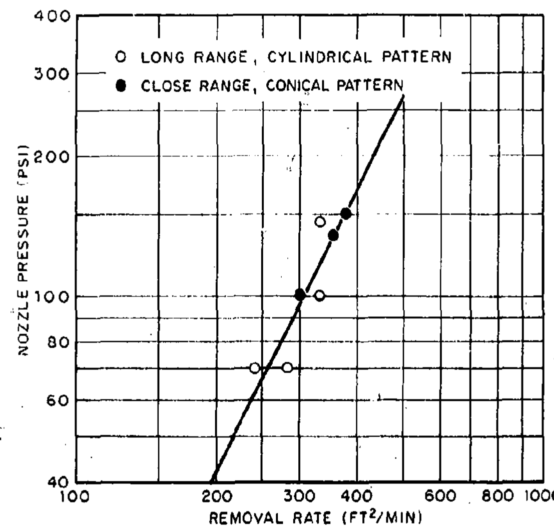


Fig. A.3 Performance Curves for the 7/16 inch Forester Nozzles

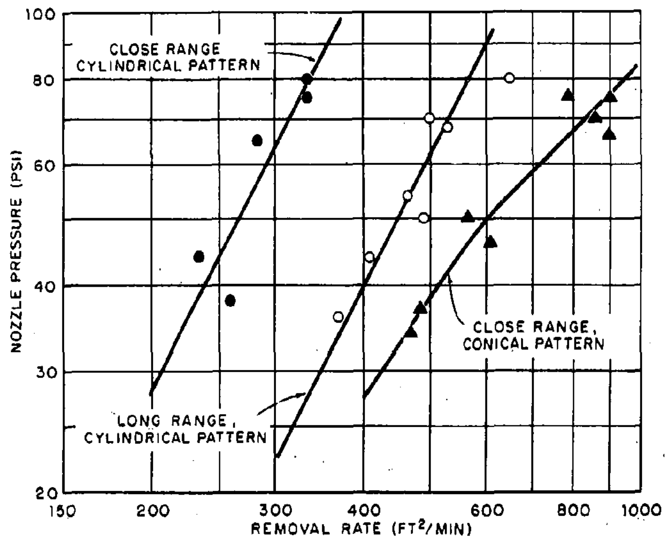


Fig. A.4 Performance Curves for 5/8 inch Fire Nozzles

Comparing equation A.1 and A.3; if

$$\text{slope } m = 2 \tag{A.4}$$

then

$$G' = a/C_u \tag{A.5}$$

However, orifice size "a" is constant for any one nozzle thus making C_u a constant also. Hence equation A.3 becomes

$$R = G' \, p^{1/2} \tag{A.6}$$

which is identical in form to the general expression in equation A.1 The above expression describes the dependence of rate upon pressure within the limits of the available test data. It therefore appears that, for a given removal effectiveness, increased nozzle pressure will not cause an increase in unit consumption.

During the test runs with the 5/8 inch tipped nozzles (suicide or fog) it was found that by reaching out beyond the usual range to 15 or 20 feet the cleaning rate increased 33 to 43 percent. The unit consumption was decreased an average of 41 percent causing the economy ratio ρ to increase by factors of 2-1/2 to 3. To explain this marked improvement in performance it is necessary to compare descriptions of the stream behavior for the two techniques used.

When directing the stream at close range, 6-8 feet from the nozzle, the pattern is usually cylindrical and compact. Because the resulting impact region is only a few inches square, the stream cannot be readily made to provide the coverage necessary to maintain a high rate of removal. In addition, the angle of attack ($\sim 30^{\circ}$) is so great that an appreciable fraction of the flow is wasted in harmless splattering.

By contrast, working at long range allows the stream to open up, thus providing an impact region of approximately one foot square. Reaching 15 or 20 feet flattens the attack angle ($\sim 10^{\circ}$) to such an extent that splattering is almost eliminated. Most of the water, upon striking the surface, scoots forward 10 feet or more before losing its cleaning power. In this way the removal action is taking place over an area which exceeds that of the initial impact region by several square feet. This larger coverage plus the more complete utilization of the stream's available energy appears to be largely responsible for the improvement observed. It is also possible that this water which ranges far ahead of the main stream may condition the contaminant in advance making it fluid and thus more readily removable.

Because of the above findings, the 1-1/2 inch Forester* nozzles having 1/2 inch and 7/16 inch tips, respectively, were tested at long range only. Table A.5 indicates that these nozzles, when so employed, exhibited greater economy ratios than the larger nozzles (5/8 inch tip size) used at close range. This further substantiates the advantage of the long range technique.

Two special 3/8 inch nozzles on 1 inch lances were tested and found unsatisfactory. Their stream patterns were too small (even at ranges longer than 8 feet) to permit high removal rates. Low economy ratios are also evident in this case.

In order to increase the size of the impact region without increasing the range, the tips of four nozzles were reamed so as to create conical stream patterns. Test results for these nozzles are shown in the latter half of Table A.5. For the larger nozzles, 5/8 and 1/2 inch orifices, the performance of conical patterns demonstrated a definite improvement in cleaning efficiency. Rates and economy ratios went up appreciably as unit consumption decreased. Unfortunately, with the creation of the conical stream pattern, a pulsating reaction occurred at the nozzle. This pulsation was too strong for the nozzle man to ignore, since he was kept off balance trying to oppose the fluctuating thrust. For this reason the reammed nozzles could not be recommended and were not used later during Stoneman II tests. In principle the close range conical stream is promising, but a simple means must be found to form such a pattern without the attendant pulsation.

Performance of a Forester nozzle with a 3/8 inch tip was better than with the reammed version of either the 3/8 or 7/16 inch tips. This nozzle gave a conical stream pattern naturally (without reaming) and appeared to be more efficient than fire nozzles with conventional 5/8 inch orifices. However, the latter type proved to be capable of significantly greater rates and economy ratios, as eventually discovered in the full scale dress rehearsals just prior to Stoneman II. Results of these and other runs are given at the bottom of Table A.5.

The foregoing firestream tests culminated in the choice of a nozzle with a 5/8 inch orifice for the actual field tests. Since the more expensive fog nozzle offered no particular advantages, the suicide model or plain fire nozzle was finally selected. The nozzle was, of course, to be used in conjunction with the long range techniques. In developing this technique, it appeared that a flatter attack angle would further improve the removal performance. This means lowering the nozzle from about three feet to perhaps one foot above the surface.

*The Forester nozzle like the suicide nozzle is a conventional fire nozzle. However, it can be fitted with various tips and thereby reduce the orifice size.

Obviously, manual control of a high thrust nozzle in such a position is not practical. However, the means of attaining this advantage should not be overlooked.

Development of a suitable nozzle for building roofs required additional testing of nozzles providing a fan shaped pattern. These nozzles were referred to as fan nozzles, and the results of their tests are entered in Table A.6. The tabled data together with the appropriate pressure/rate curve of Fig. A.5 indicate that the performance characteristics of the 15 and 35 degree fan nozzles were almost identical. As in the case of the fire nozzle tests, the curve is a straight line having a positive slope of 2 denoting a constant unit water consumption.

A varied performance was exhibited by an 80 degree fan nozzle, although it seemed competitive with the above nozzles when under a pressure of 150 psi. Even so, the stream pattern was too wide, making it difficult to direct the run off along a unidirectional path. Considerable contaminant was inadvertently pushed to both sides despite all efforts to contain it. From this and the previous nozzle runs, it was concluded that a fan angle near 35 degrees would be satisfactory.

Because of their small size and restricted flow, the removal rates achieved with the fan nozzles were not generally as high as those for the fire nozzles. For this reason a larger nozzle designed with an eliptic orifice was fabricated and tested. Table A.6 shows the results of tests for two orifice sizes, a 3/8 X 9/16 inch orifice and a 3/8 X 1/2 inch orifice, respectively. From these results it is evident that the larger eliptic (3/8 X 9/16) was by far the most promising of the two. Since the runs were carried out on a composition roof where freedom of movement was very limited, the performance of the eliptical fan nozzles was proportionately limited. Rates were lower and unit consumption was higher than for the smaller nozzles tested previously on pavement. Even under these conditions, the performance curve for the large eliptic appeared to hold to the straight pattern established by all its predecessors (see Fig. A.5). Again, the slope had a value of 2.

A set of experiments was carried out on a tar and gravel roof. Four different nozzles were used as shown at the bottom of Table 6. Although the removal rate varied from 71 to 91 ft^2/min and the consumption varied from 640 to 910 gal/1000 ft^2, the economy ratio remained almost constant. Whether this is a peculiarity of tar and gravel roofs remains for further testing to decide.

TABLE A.6

Fan Nozzle Tests

Nozzle Type	Fan Angle (degrees)	Orifice (in.)	Press (psi)	Flow (gpm)	Rate (ft^2/min)	Unit Cnsmptn $\frac{gal}{1000\ ft^2}$	Econ. Ratio (ρ)
			Pavements				
U80200*	80	11/32	110	32	222	145	1.53
			110	32	250	128	1.97
			150	38	310	123	2.52
			200	44	250	176	1.42
P35100*	35	1/4	130	18	167	108	1.54
			200	22	200	110	1.82
			260	25	250	100	2.50
P15100*	15	1/4	150	20	181	111	1.63
			200	24	222	108	2.06
			280	28	274	102	2.68
			Composition Shingles				
U25200*	25	—	95	31	74	420	0.18
Eliptic	30	3/8 X 9/16	40	37	117	315	0.37
			104	62	210	295	0.71
			108	62	190	326	0.58
Eliptic	20	3/8 X 1/2	150	58	152	380	0.40

Continued

TABLE A.6 (Contd)

Fan Nozzle Tests

Nozzle Type	Fan Angle (degrees)	Orifice (in.)	Press (psi)	Flow (gpm)	Rate (ft^2/min)	Unit Cnsmptn $\frac{gal}{1000\ ft^2}$	Econ. Ratio (ρ)
			Tar and Gravel				
Eliptic 1 in. Lance 1-1/2 in.	20	3/8 x 1/2	155	60	81	750	0.107
		3/8	165	45	71	640	0.110
		7/16	135	62	81	770	0.104
Forester 1-1/2 in. Suicide		5/8	60	88	97	910	0.106

*Model number of Spraying System Co.

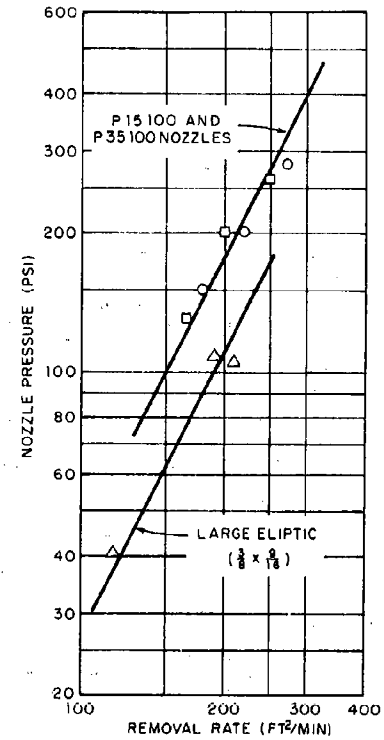


Fig. A.5 Performance Curves for Water Broom Nozzles

Street Flusher Tests

While the previous tests were taking place the powered street flusher (used during the STONEMAN I operation) was being equipped with new piping, valves, nozzles and a larger pump rated at 500 gpm. Because of their excellent condition, permission was obtained from Pacific Reserve Fleet to use the concrete paved areas at the lower ends of piers 1 and 2. The first set of runs was made on a contaminant mass level of 100 g/ft^2. As before, speeds were controlled so as to provide a visual removal of approximately 95 percent of the non-radioactive dirt simulant.

Upon the basis of the lower flow rates and strong impacts noted during the preliminary studies, flusher nozzles were gapped for an orifice setting of 3/64 of an inch. This immediately proved to be a critical setting at pressures in excess of 50 psi. The fan shaped jets broke up into distinct fingers above this pressure and combed through the contaminant leaving behind large streaks of mud. It was then decided to try the next larger spacing, 1/16 of an inch. Trial runs showed this setting to be satisfactory.

In order to push the contaminant aside and out of the way of the truck's wheels, only three of the four available nozzles could be used. The two front nozzles were adjusted so that their jets intersected the pavement in a continuous straight line. Trial runs showed that, whenever the continuity of this intersection line was broken, streaking resulted. The left side nozzle (just behind the driver) was aimed so as to pick up where the left front nozzle left off in the removal process. Because all three nozzles had to be matched to provide sufficient overlapping of the jet streams, it was not possible to make the attack angles all equal at 30 degrees. This angle was, therefore, used as only a rough guide in adjusting the nozzle array.

Table A.7 contains the results of the flusher tests, the more important runs being those involving the 100 g/ft^2 mass levels. Average values of the tabled data have been plotted in Figs. A.6 through A.9 The solid curves apply to flusher performance and the dashed lines apply to hosing systems involving several fire nozzles (5/8 inch tip). With the exception of the curve for consumption, the three remaining curves have been normalized at 30 psi.

Figures A.6, A.7 and A.8 clearly demonstrate the superior properties of a powered flusher system, by the rapid divergence of the dashed and solid curves with increasing pressure. For example, in the range from 30 to 55 psi a flusher will exhibit the following advantages over a comparable hose and fire nozzle system:

TABLE A.7

Street Flusher Tests

Nozzle Type Arrangement	Orifice Size (in.)	Mass Level (g/ft²)	Press. (psi)	Flow (gpm)	Rate (ft²/min)	Unit Cnsmptn $\frac{gal}{1000\ ft^2}$	Econ. Ratio (ρ)
			Preliminary Tests				
Conventional 3 Nozzles	1/16 X 8-1/2	100	30	320	1730	185	9.4
			30	320	2040	157	13.0
			30	320	2100	152	13.8
			35	348	1800	193	9.3
			35	348	2000	174	11.5
			40	378	2140	177	12.1
			40	378	2570	147	17.5
			40	378	2650	143	18.5
			45	410	2500	164	15.2
			45	410	2500	164	15.2
			45	410	2720	151	17.9
			45	410	3000	137	21.8
			50	450	2730	165	16.6
			55*	480	3100	155	20.0
			55	480	3220	149	21.6
			55	480	3430	140	24.5
			55	480	3600	133	27.0
		100	55	480	3900	123	31.7
		30	30	320	9500	34	280
		30	50	443	11200	40	280
		10	35	348	9500	36	264
		10	50	443	11200	40	280
Improvised 4 - U40200's	11/32	100	65	102	1280	80	16.0
		100	65	102	1500	68	22.1
			Stoneman II Dress Rehearsals				
Conventional 3 Nozzles	1/16 X 8-1/2	100	55	480	4500	106	42.2
		100	55	480	5130	93	55.2

*Maximum pressure obtainable for nozzle setting of 1/16 inch.

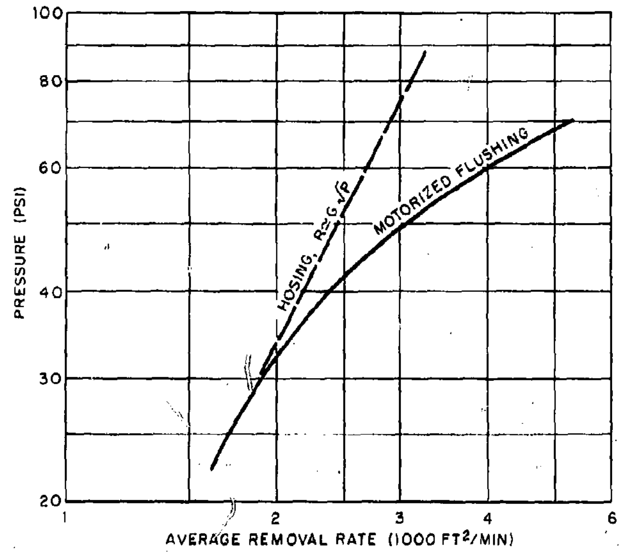


Fig. A.6 Comparative Increase in Removal Rate With Increased Nozzle Pressure

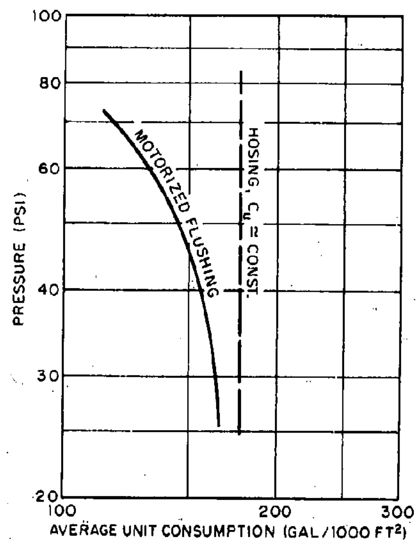


Fig. A.7 Comparison of Average Unit Consumption With Increased Nozzle Pressure

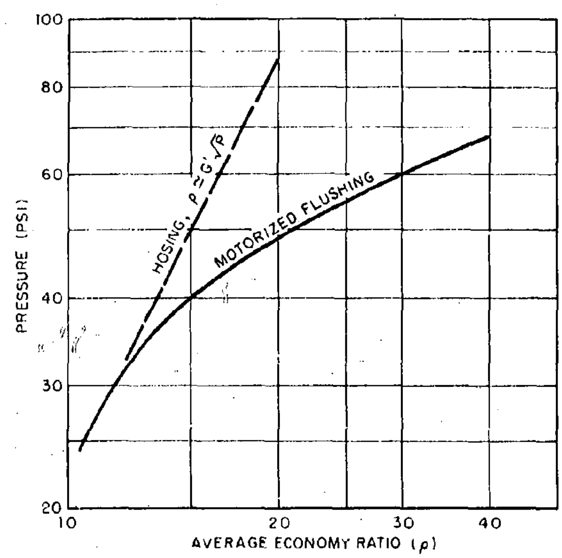


Fig. A.8 Comparative Increase in Economy Ratio With Increased Nozzle Pressure

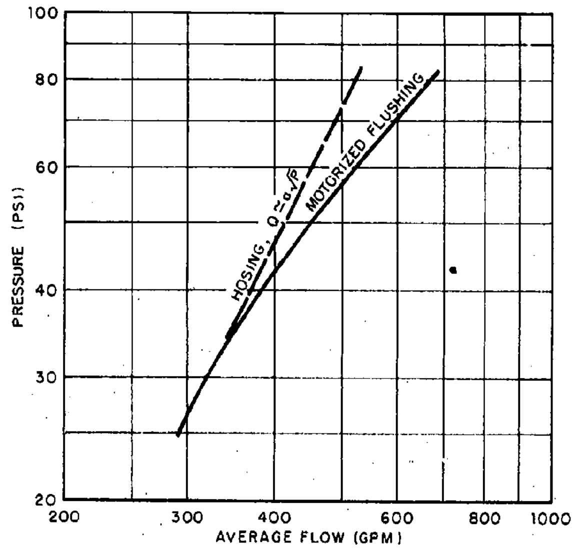


Fig. A.9 Comparative Increase in Average Flow With Increased Nozzle Pressure

(1) Rate gains of 1/3,
(2) Consumption savings of 1/3,
(3) Economy ratio gains of 2/3.

The shape of these curves indicates that the advantages would become even greater at higher pressures. Because more powerful pumping systems than the one installed are available, the attainment of these pressures is not likely to impose an immediate limit upon rate. The restriction in the form of a safe speed limit will undoubtedly occur first. Further testing will probably show that, because of the nature of the soil contaminant, a maximum rate exists beyond which removal can no longer be effectively accomplished. It was found during the early testing that 30 psi was the minimum pressure limit for complete removal (95 %). The corresponding rate was 1900 ft^2/min. Although this was the optimum rate for 30 psi, it may be thought of as the minimum flushing rate in consideration of higher and more desirable pressures.

The unit consumption curve in Fig. A.7 appears to have been at a near maximum value when pressure was 30 psi. Its apparent approach, with decreasing pressure, to the constant value of 177 gal/1000 ft^2 for firehosing (shown by the dashed line) is merely coincidental. As the pressure increases well beyond 55 psi, the unit consumption curve will no doubt approach some lower limiting value asymptotically since, by definition, it can never become zero. If this is true, the slope of the removal curve will become more nearly constant.

The curve for volume of water used per unit of time, as shown in Fig. A.9, demonstrates flushing, in this connection, to be at a slight disadvantage. The curve is actually a calibration curve for the combined flow of all three flusher nozzles. As such, it points up a weakness in the nozzle design - not the flusher system or its capability. Because of the long narrow orifice shape (8-1/2 X 1/16 inches) and the lack of structural reinforcement, the nozzle lips were able to separate under increased pressures. This enlarged the effective orifice area and permitted excessive flow. An improved and simplified nozzle design would correct this condition. The solid curve would then coincide with the dashed line shown in Fig. A.9.

Limited runs were made on mass levels of 30 and 10 g/ft^2. As shown by the values in Table A.7 the performance was much higher, in every respect, than for previous runs on 100 g/ft^2. Optimum performance in the 10 gram case could not be determined, due to the fact that flusher speeds could not be increased further for fear of driving off the end of the pier.

Results of two runs made with an improvised nozzle system are included in the table. This system consisted of four manifolded U40200* flat jet nozzles mounted on the front of the street flusher. Attack and azimuth angles were set at 30 and 60 degrees respectively in accordance with the findings of the jeep flusher tests made earlier.

In order to establish a basis for comparison between this improvised system and the conventional flusher system tested earlier, the data for the former must be adjusted to a 14 nozzle arrangement. Such an improvised system (I) provides about the same coverage (7 feet) as the conventional flusher (c) and a comparison gives the following results;

(1) $(\text{Rate})_I \simeq (\text{Rate})_c$

(2) $(\text{Consumption})_I \simeq 1/2\ (\text{Consumption})_c$

(3) $\rho_I \simeq 3/2\, \rho_c$

Although the comparisons appear optimistic, they serve to demonstrate the feasibility of improvised systems as a substitute for conventional flushers.

Nozzle Calibrations

Figure A.10 contains the nozzle calibration curves for the four individual types of nozzles eventually used at the STONEMAN II tests. The two curves at the extreme right hand side of the figure give the flow behavior of nozzle combinations comprising improvised and conventional flusher systems, respectively, as used at Operation STONEMAN II.

PRELIMINARY FINDINGS

1. Within the anticipated limits (1 to 3 ft for fixed nozzles and 1 to 8 ft for hand held nozzles) the impact of water streams doesn't diminish significantly with increased range.

2. For fixed nozzles which have flat fan shaped streams, as proposed for street flushers, removal effectiveness and economy ratios are highest for attack angles between 30 and 45 degrees and an azimuth angle of about 60 degrees.

3. Flusher tests showed that to prevent streaking and thereby achieve the desired removal effectiveness, the two front nozzles must be matched so that the water jets impinge on the pavement in an uninterrupted straight line.

*Spraying Systems Co. model number.

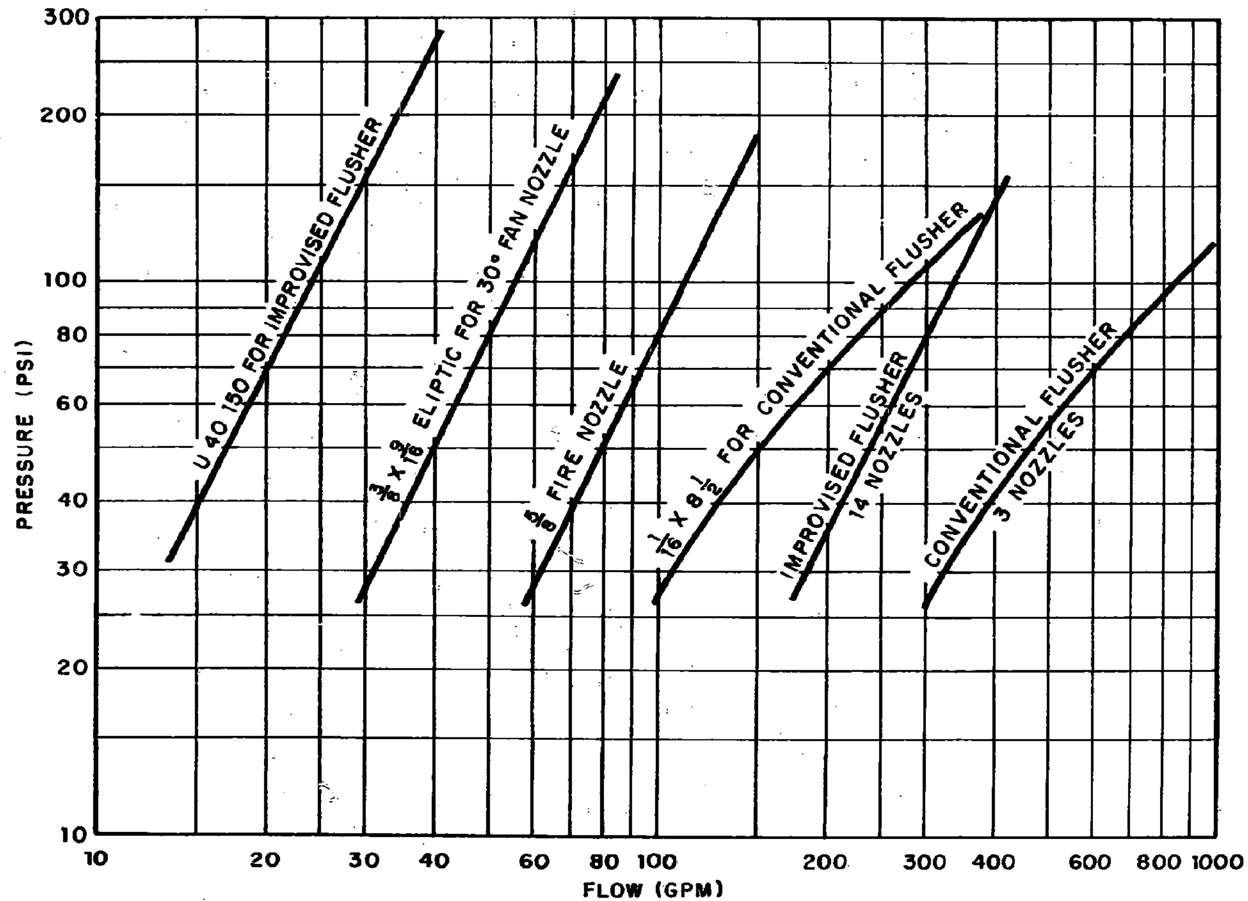


Fig. A.10 Nozzle Calibration Curves

4. In the case of hand held nozzles having cylindrical streams, long range application at small attack angles (about 10 degrees) permits optimum removal rates. The standard 1-1/2 in. fire nozzle with a 5/8 in. orifice proved to be the best of those tested when operated at a range of 15 to 20 ft.

5. Conical streams are very effective at close range, but the attendant pulsation in the stream's thrust creates excessive fatigue to the nozzle man.

6. The best design of a nozzle suitable for building roofs is a 1 inch nozzle with a 3/8 X 9/16 eliptic orifice which provides a relatively flat fan shaped stream having an included angle of about 30 degrees.

7. The trial nozzle system for improvised street flushing appears to be equal or better than the conventional arrangement from the standpoint of rate, consumption and economy ratio.

8. Because of the greater rates possible, increased nozzle pressure causes no increase in unit consumption. In fact, unit consumption even decreases with higher pressures and rates (see Fig. A.7) when motorized flushing is employed.

The above findings are restricted to initial mass loadings of 100 g/ft^2 and a removal effectiveness of 95 %.

APPENDIX B

B.1 OBSERVED DATA

The following tables present for each test the radiation measurements obtained at the monitoring locations on the test areas. The measurements have been background-corrected and decayed to the mid-time of the initial readings. All measurements were taken with the Mobile Shielded Gamma Detector Unit described in Volume I of this series of reports. Table B.1, B.2 and B.3 present the raw data utilized to obtain the effort required for each surface-method combination.

A map of Camp Stoneman indicating the various test areas is shown.

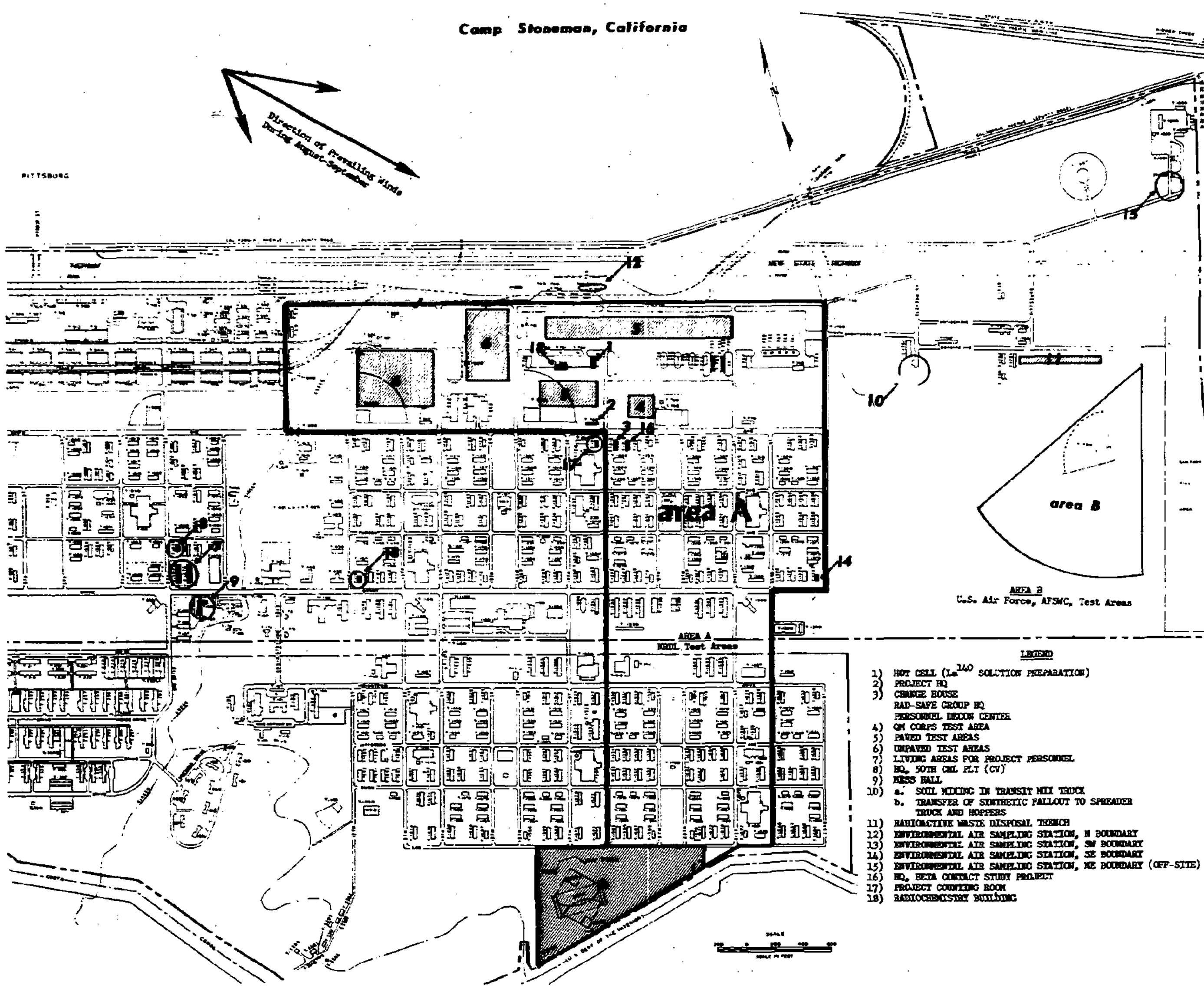

Camp Stoneman, California
Direction of Prevailing Winds During August-September
PITTSBURG
NEW STATE HIGHWAY
area A
area B
AREA A
NRDL Test Areas
AREA B
U.S. Air Force, AFSWC, Test Areas
LEGEND
1) HOT CELL (La140 SOLUTION PREPARATION)
2) PROJECT HQ
3) CHANGE HOUSE
RAD-SAFE GROUP HQ
PERSONNEL DECON CENTER
4) QM CORPS TEST AREA
5) PAVED TEST AREAS
6) UNPAVED TEST AREAS
7) LIVING AREAS FOR PROJECT PERSONNEL
8) HQ, 50TH CML PLT (CV)
9) MESS HALL
10) a. SOIL MIXING IN TRANSIT MIX TRUCK
b. TRANSFER OF SYNTHETIC FALLOUT TO SPREADER TRUCK AND HOPPERS
11) RADIOACTIVE WASTE DISPOSAL TRENCH
12) ENVIRONMENTAL AIR SAMPLING STATION, N BOUNDARY
13) ENVIRONMENTAL AIR SAMPLING STATION, SW BOUNDARY
14) ENVIRONMENTAL AIR SAMPLING STATION, SE BOUNDARY
15) ENVIRONMENTAL AIR SAMPLING STATION, NE BOUNDARY (OFF-SITE)
16) HQ, BETA CONTACT STUDY PROJECT
17) PROJECT COUNTING ROOM
18) RADIOCHEMISTRY BUILDING

TABLE B.1

Raw Data for Decontamination Rate and Effort on Pavements

Test	Date	Area ft²	Time min	No. of Nozzles	Nozzle Pressure psi	No. of Passes(1)	Rate(2) ft²/min	Effort(2) man-min/ 10^4 ft²	Speed(2) mph
					Conventional Motorized Flushing				
A1	8/27	6000	1.48	3	45	5	4050	2.47	5.76
A2	8/21		1.6	3	55	5	3750	2.66	5.3
A3	8/25		3.25	3	55	5	1845	5.42	2.63
A4	8/30		0.8	3	55	5	7500	1.33	10.65
A5	9/15		1.10	3	55	5	5450	1.83	7.74
A5i	9/16		-	3	55	5	5350	1.87	7.6
A6	8/25		1.8	3	45	5	3330	3.00	4.74
A7	8/30		0.55	3	55	5	10900	0.92	15.5
A8	8/30		0.75	3	55	5	8000	1.25	11.34
A8i	9/19		0.73	3	60	5	8220	1.21	11.7
A9	8/26		1.11	3	55	5	5420	1.85	7.67
A10	9/19	4500	0.67	3	60	4	6720	1.49	9.50
A11	9/16	2800	0.66	3	55	3	4250	2.36	7.23
A12	9/1	4500	1.56	3	55	4-1/2	2890	3.47	4.59
A13	9/13	12500	2.0	3	55	4(3)	6250	1.60	11.4
A14	9/20	12500	-	3	60	4(3)	2550	3.92	4.64
A40S(4)	9/20	5000	-	-	N.A.	6	1920	5.2	5.25
A40F	9/20	5000	0.88	3	60	4	5700	1.76	10.3
					Improvised Motorized Flushing				
A15	9/15	6000	1.42	14	85	6	4220	2.36	7.20
A16	8/29		1.57	14	85	6	3820	2.62	6.52
A17	9/1		2.14	14	85	6	2800	3.56	4.78
A18	9/5		0.77	14	85	6	7800	1.28	13.27
A19	9/17		1.22	14	90	6	4920	2.03	8.38
A20	9/10		-	14	90	-	3975	2.51	6.7
A20i	9/13		-	14	85	-	4690	2.13	7.98
A21	9/15	4500	0.72	14	80	5	6250	1.60	11.03
A22	9/17	4500	1.1	14	80	5	4090	2.44	7.25
A23	9/13	4500	-	14	85	5	2600	3.84	4.57

(1) No. of adjacent passes for one complete coverage of test area.
(2) Computed.
(3) Flushed 2 passes in each direction.
(4) S = Sweeping
F = Flushing
NA = Not Applicable

TABLE B.2

Raw Data for Decontamination Rate and Effort:
Firehosing Pavements

Test	Date	Area ft²	Time min.	No. of Nozzles	Nozzle Pressure psi	No. of Men	Rate(1) ft²/min	Effort(1) man-min/ 10^4 ft²	Speed(1) ft/min
A24	8/30	6000	4.1	2	75-80	5	1460	34.1	36.5
A25	9/2		4.43		75-80		1360	36.9	33.9
A25i	9/13		4.1		75		1460	34.1	36.5
A25ii	9/18		5.6		75		1070	46.6	26.8
A26	9/4		10		78-80		600	83.3	15.0
A26i	9/18		5.65		75		1060	47.1	26.5
A27	8/30		2.2		75-80		2720	18.3	68.2
A28	9/2		3.08		75-80		1950	25.7	48.7
A29	9/6		8.7		75		690	72.4	17.2
A30	9/5	4000	2.5		75		1600	31.3	40.0
A31	9/9	4500	4.0		75		1126	44.5	35.0
A32	9/18	4000	4.36		75		916	54.5	22.9

(1) Computed values.

TABLE B.3

Raw Data for Decontamination Rate and Effort on Roofs

Test	Date	Area (ft^2)	Time (min)	No. of Nozzles	Nozzle Press (psi)	No. of Men	Rate (ft^2/min)	Effort $\frac{\text{man min}}{10^3\ ft^2}$
				30° Fan Nozzle on Tar and Gravel				
AR 1	9/8	1440	12	2	150	6	120	50
2	9/17		9				160	37.5
3	9/4		12				120	50
4	9/8		9.2				158	38.4
5	9/17		6.7				214	27.9
6	9/13		8				180	33.4
				30° Fan Nozzle on Composition Shingles				
AR 7	9/8	990	2.9	1	120	3	340	8.8
8	9/9	1500	4.7				320	9.4
9	9/12	990	7				140	21.2
10	9/15	1500	2.35				640	4.7
11	9/9	1500	3.3				455	6.6
12	9/13	1500	3.75				400	7.5
				Lobbing of Fire Streams on Composition Shingles				
AR 13	9/15	1665	6.7	1	40	3	250	12.1
14	9/19	1620	6.1				265	11.3
15	8/25	1708	9				190	15.8

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-1	SURFACE TYPE	A-C
DATE	27 Aug. 1958	AREA NO.	A-17
PROCEDURE	CMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

5799	5220	6385	6395	4241	4236	3943	4691	4725	4708	5385
6304	5511	4272	4164	4589	5800	5616	4774	4787	4178	4971
6316	6542	5408	5689	5530	5435	4718	9137	4521	4593	5915

R_R

← Direction of Decontamination

186	213	202	179	160	148	150	153	148	144	98
322	276	274	264	236	172	194	231	197	148	162
383	334	248	269	217	244	225	203	222	177	183

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-2 SURFACE TYPE A-C

DATE 21 Aug. 1958 AREA NO. A-22

PROCEDURE CMF AREA SIZE 40' x 150' (6000 sq. ft.)

I_R

+	+	4562	3600	2376	2204	2307	1546	2719	2454	5783
+	+	+	5133	4677	4621	3563	5365	4420	5539	4303
+	+	+	4000	3534	4338	3775	4639	2880	3058	2785

R_R

165	105	160	117	107	121	190	123	135	187	138
192	222	231	255	297	206	206	249	197	232	164
118	119	110	110	199	140	125	114	124	83	83

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-3	SURFACE TYPE	A-C
DATE	25 Aug. 1958	AREA NO.	A-23
PROCEDURE	CMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

5674	11811	8826	7037	10140	7703	7105	10827	10056	9455	12806
7007	10452	10507	10740	11773	12709	10360	11259	12102	10503	12064
12677	10572	9423	13508	11325	12597	10901	7084	5686	6298	1407

R_R

171	148	118	125	95	94	79	85	80	95	60
129	282	137	141	136	83	74	54	63	54	37
1112	89	126	146	75	49	40	48	39	30	27

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-4	SURFACE TYPE	A-0
DATE	30 Aug. 1958	AREA NO.	A-14
PROCEDURE	OMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

3414	2808	2706	2810	2913	2981	2865	2403	2756	3075	3975
3520	3989	5219	5699	5681	4559	3956	4424	5182	5161	4693
4798	4841	5352	5247	5275	5292	5749	6128	6184	6351	4644

R_R

396	176	205	208	158	179	179	215	143	160	132
195	236	212	195	234	272	157	152	153	176	158
762	1080	586	1485	376	264	296	267	237	213	125

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-5

DATE 15 Sept. 1958

PROCEDURE CMF

SURFACE TYPE A-C

AREA NO. A-10

AREA SIZE 40' x 150'
(6000 sq. ft.)

I_R

4523	5458	6397	6349	7057	5989	7599	7734	6373	5980	7558
8700	6665	5206	8115	5889	5897	7541	6771	5842	6400	3889
7480	6862	6823	7379	5535	5865	6527	7370	6353	5663	5829

R_R

200	148	225	226	271	206	270	235	226	228	171
285	259	210	259	230	192	229	254	237	276	202
463	336	339	378	406	322	424	293	276	233	155

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-51	SURFACE TYPE	A-C
DATE	19 Sept. 1958	AREA NO.	A-19
PROCEDURE	CMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

5450	6554	7316	6411	8115	8340	6593	7880	8268	6335	7936
5173	6264	2997	3225	2872	2555	3418	1125	1916	3916	4415
5489	6673	6089	3791	6265	5695	4885	3381	3906	5802	5261

R_R

186	186	158	188	151	129	127	126	150	70	78
156	159	175	216	321	224	163	300	133	114	83
220	190	191	288	264	241	532	189	171	161	99

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-6	SURFACE TYPE	A-C
DATE	25 Aug. 1958	AREA NO.	A-19
PROCEDURE	CRF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

7073	6120	6482	5415	5558	5041	5837	5709	6361	7106	7732
14026	11584	10849	13467	9958	10423	13020	8035	10930	10563	6076
10037	13005	13516	10716	11429	8387	8005	8835	8505	7446	10431

R_R

2042	1735	2340	1415	976	1662	2330	2635	2060	334	814
166	122	166	182	181	173	149	144	120	113	91
2240	1060	371	282	225	217	490	182	180	140	112

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-7 SURFACE TYPE A-C

DATE 30 Aug. 1958 AREA NO. A-1

PROCEDURE C.F AREA SIZE 40' x 150'

(6000 sq. ft.)

I_R

3868	4123	4087	3827	3680	3921	3754	2918	3389	3602	3033
4950	4646	3636	4039	4654	5824	5983	5725	4826	4795	5281
3171	3198	3442	3991	4584	4848	4490	4002	4112	4371	4488

R_R

535	515	1070	612	621	612	670	395	341	547	597
278	213	223	378	356	512	391	448	285	189	175
820	1200	1090	746	1140	704	726	460	338	320	199

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-8 SURFACE TYPE A-C

DATE 30 Aug. 1958 AREA NO. A-16

PROCEDURE C.F AREA SIZE 40' x 150' (6000 sq. ft.)

I_R

8879	8281	9611	8203	9404	8161	10002	8473	9698	8021	7913
10162	10859	10752	11529	10340	10525	11232	10280	12404	9847	13877
10008	12306	10584	12931	10784	13346	11299	11335	11379	11021	11789

R_R

900	322	363	246	200	212	443	306	432	280	268
857	566	344	306	494	333	402	318	331	331	271
765	1380	932	516	568	445	399	582	394	337	258

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-81 | SURFACE TYPE A-C
DATE 19 Sept. 1958 | AREA NO. A-16
PROCEDURE CMF | AREA SIZE 40' x 150'
(6000 sq. ft.)

I_R

3349	3212	3522	3407	3040	3325	3673	3238	3542	3604	2907
4527	3880	4869	3680	3837	4808	4143	4173	5380	3868	5116
4289	5250	4457	4406	5047	4305	4501	5529	3871	4092	4943

R_R

147	124	127	105	97	93	98	90	78	94	66
201	146	110	85	96	87	92	94	104	99	68
256	488	119	135	141	133	120	168	100	90	86

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-9	SURFACE TYPE	A-G
DATE	26 Aug. 1958	AREA NO.	A-10
PROCEDURE	GMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

6968	8611	8584	6815	7837	7925	6629	7853	7874	7496	9472
8981	8381	9370	9870	8043	7531	9421	7476	7326	8606	7624
9765	8493	8240	10039	9117	8420	9263	8660	7275	8106	9147

R_R

268	360	193	155	232	197	418	369	1115	1785	772
164	208	143	148	136	129	174	135	126	141	111
870	418	507	293	300	270	1030	2395	3920	167	134

TEST DATA SHEET
12ND NRDL-1002 (6/59)

TEST NO.	A-10	SURFACE TYPE	P-C
DATE	19 Sept. 1958	AREA NO.	A-30
PROCEDURE	CMF	AREA SIZE	32' x 140' (4500 sq. ft.)

T_R

1860	1743	2043	2228	2074	2252	2443	2517	2501	2727	2409
1593	1497	1732	2116	1998	1575	1759	2198	1444	1666	1472

Seam

R_R

72	169	257	208	160	91	43	132	53	61	24
65	69	80	45	43	33	39	613	68	49	39

TEST DATA SHEET
12ND NRDL-1002 (6/59)

TEST NO. A-11 SURFACE TYPE P-C

DATE 16 Sept. 1958 AREA NO. A-31

PROCEDURE CMF AREA SIZE 32' x 140' (4500 sq. ft.)

I_R

9363	9871	9057	9775	9983	9189	8981	8970	9310	8677	7782
5918	4955	6686	6928	3934	5653	5124	6759	5860	4517	6572

Seam

R_R

185	165	143	214	98	87	74	725	38	25	24
147	110	127	80	84	103	69	1119	50	74	84

TEST DATA SHEET
12ND NRDL-1002 (6/59)

TEST NO. A-12

DATE 1 Sept. 1958

PROCEDURE CMF

SURFACE TYPE P-C

AREA NO. A-30

AREA SIZE 32' x 140' (4500 sq. ft.)

I_R

11384	13180	11816	11184	11204	12526	9824	12854	11471	11232	12452
10937	10742	11656	12807	12133	13127	14368	12632	14738	15229	14050

Seam

R_R

146	140	301	706	140	129	112	968	129	121	116
223	218	205	219	552	214	229	1460	208	166	141

TEST NO. A-13

DATE 13 Sept. 1958

PROCEDURE CMF

SURFACE TYPE A-C

AREA NO. A-32

AREA SIZE 32' x 500' (16000 sq. ft.)

I_R

1909	2520	1894	2546	2821	1890	2264	1488	2225	3233	2154	2010	1683	2756	1894	1596	2015	2453	1830	1177		
2511	1750	1685	2292	2752	2880	2482	2863	2509	2744	2921	3265	3809	2094	2915	2198	2945	3861	2235	2356		

R_R

Direction of Decay →

87	31	57	48	55	69	80	73	63	110	49	114	161	127	161	319	262	144	112	129		
43	42	50	58	57	45	56	60	50	54	56	59	126	108	112	131	116	106	112	71		

TEST DATA SHEET 12ND NRDL-1003 (6/59)

TEST NO. A-14

DATE 20 Sept. 1958

PROCEDURE CMF

SURFACE TYPE A-C

AREA NO. A-32

AREA SIZE 32' x 500'

(16000 sq. ft.)

I_R

10157	12684	11747	9910	10380	10869	10767	10495	9746	9613	8371	7847	9867	9881	9756	10257	10267	10785	12798	12723	13237	
11498	13208	13113	12465	10785	13365	13254	11586	10474	10076	9676	12578	11736	10615	9437	9112	10713	13845	13196	11800	13721	

R_R

Direction of Decon →

62	91	99	83	77	55	85	34	42	38	50	67	135	103	89	93	156	248	226	236	246	
91	104	90	71	56	38	29	32	31	26	37	44	44	55	73	117	171	169	155	151	121	

TEST DATA SHEET 12ND NRDL-1003 (6/59)

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-15 SURFACE TYPE A-C

DATE 15 Sept. 1958 AREA NO. A-6

PROCEDURE IMF AREA SIZE 40' x 150' (6000 sq. ft.)

I_R

5830	5354	5608	4320	3788	4296	5095	5459	5434	4290	4053
4918	4091	2859	2160	2828	2915	3783	3544	2857	2786	2061
5232	4345	3914	3782	4227	4259	5063	3160	3110	3406	2973

R_R

1845	211	1120	211	545	163	165	131	135	107	152
370	271	193	196	184	214	1380	146	145	175	137
346	258	211	206	240	251	253	191	186	159	147

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-16	SURFACE TYPE	A-C
DATE	29 Aug. 1958	AREA NO.	A-8
PROCEDURE	IMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

10674	11493	12283	10412	11741	10231	11810	10476	11143	9131	9052
11453	9297	12109	9595	10520	9537	10933	9728	10494	8650	10850
8971	11226	8144	11660	10232	12143	8587	11208	8471	11116	8103

R_R

123	126	112	130	204	244	258	238	254	250	59
417	440	326	282	294	331	265	263	210	218	266
684	440	398	385	405	338	313	315	348	317	306

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-17	SURFACE TYPE	A-C
DATE	1 Sept. 1958	AREA NO.	A-18
PROCEDURE	IMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

14657	14044	12857	14061	13310	12212	12313	11391	11149	11446	10883
12506	10585	13881	13184	9836	6582	7531	8531	12288	12268	11851
12154	14530	13117	11700	15280	12121	12719	14237	11985	11937	13900

R_R

128	185	152	167	207	428	378	91	91	81	83
240	162	160	169	161	144	134	171	141	139	152
444	373	263	214	198	383	265	208	217	132	87

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-18

SURFACE TYPE A-C

DATE 5 Sept. 1958

AREA NO. A-7

PROCEDURE IMF

AREA SIZE 40' x 150' (6000 sq. ft.)

I_R

4422	4791	4405	3499	3485	3796	4541	4837	4359	3512	3023
4459	4666	4093	3659	3261	4179	4380	4101	3749	3189	3326
3858	4127	4153	4150	4160	4738	4509	4253	3722	3746	3858

R_R

99	123	117	155	93	75	85	67	139	88	222
319	291	454	254	335	1330	246	230	150	178	159
344	296	337	440	361	272	244	200	174	179	154

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-19	SURFACE TYPE	A-C
DATE	17 Sept. 1958	AREA NO.	A-18
PROCEDURE	IMF	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

7372	3799	5357	4306	3224	3326	2549	4030	7437	4344	3697
6913	7293	4799	6492	5858	6711	4865	5761	5987	6029	4009
5694	4534	5742	4295	5332	5407	4781	5323	5364	6691	5934

R_R

283	235	236	176	97	91	93	79	77	80	48
164	176	162	142	133	124	134	142	124	122	79
356	148	156	136	153	99	104	111	107	114	80

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-20
DATE 10 Sept. 1958
PROCEDURE IMF

SURFACE TYPE A-C
AREA NO. A-11
AREA SIZE 40'x 150' (6000 sq. ft.)

I_R

13663	14764	14398	12211	12270	13078	14969	14347	12930	15630	13400
17994	21345	18460	19510	18980	14011	16873	15494	13979	16778	14198
8607	10964	10674	10379	11611	12615	13868	13204	13423	13255	15203

R_R

238	210	193	198	208	214	198	199	170	169	161
434	649	855	390	235	269	219	207	239	196	220
287	304	326	347	342	270	352	321	194	209	204

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. [illegible]-201

SURFACE TYPE A-C

DATE 13 Sept. 1958

AREA NO. A-15

PROCEDURE IMF

AREA SIZE 40' x 150'
(6000 sq. ft.)

I_R

[illegible]	8426	8530	7397	6610	6922	8420	9661	11762	13243	12173
11522	10619	9839	10863	13004	11824	10937	9739	10377	10870	10027
10274	10791	10613	11127	10830	10934	9987	9129	8881	7501	6271

R_R

125	128	113	136	117	105	125	130	116	140	71
216	239	260	170	269	492	210	156	134	106	74
645	256	276	274	251	246	282	190	138	127	100

TEST DATA SHEET
12ND NRDL-1002 (6/59)

TEST NO.	A-21	SURFACE TYPE	P-C
DATE	15 Sept. 1958	AREA NO.	A-30
PROCEDURE	IMF	AREA SIZE	32' x 140' (4500 sq. ft.)

I_R

+	5206	5465	4765	3568	4592	5818	5999	5399	4145	4023
+	4214	4288	4445	4014	4182	3781	4047	4137	3550	3346

Seam

R_R

145	195	68	215	118	156	138	983	135	123	107
182	228	429	563	131	159	185	2251	154	185	117

TEST DATA SHEET
12ND NRDL-1002 (6/59)

TEST NO. A-22

DATE 17 Sept. 1958

PROCEDURE IMF

SURFACE TYPE P-C

AREA NO. A-30

AREA SIZE 32' x 140'

(4500 sq. ft.)

I_R

5867	5817	7589	7401	7081	6613	6566	8221	6624	6376	3300
4661	4130	3969	4887	6202	5061	5851	4477	5569	4372	4388

Seam

R_R

110	158	68	175	100	142	109	2419	93	101	54
102	105	119	130	123	97	117	2239	119	93	66

TEST DATA SHEET
12ND NRDL-1002 (6/59)

TEST NO. A-23
DATE 13 Sept. 1958
PROCEDURE IMF

SURFACE TYPE P-C
AREA NO. A-30
AREA SIZE 32' x 140' (4500 sq. ft.)

I_R

11885	11280	11540	12913	12260	11394	11113	12512	12343	10984	12313
10210	10661	8606	8439	9096	10109	9772	8532	8569	8755	9511

Seam

R_R

153	137	92	348	108	108	87	1400	96	99	97
212	169	161	135	158	114	121	1458	123	133	91

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-24 SURFACE TYPE A-C

DATE 30 Aug. 1958 AREA NO. ~~A-20~~

PROCEDURE FH AREA SIZE 40' x 150'

(6000 sq. ft.)

I_R

3978	3770	4557	4164	3950	3704	3674	3287	4171	6073	6641
4115	4251	4593	4214	3452	3483	3988	3691	4194	3457	2773
4207	4769	4633	4628	4425	4072	3724	3833	3392	3571	3427

R_R

127	136	114	206	133	119	84	124	79	86	40
149	132	128	107	185	134	400	97	83	40	32
168	240	212	284	1840	295	145	126	100	63	71

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-25 SURFACE TYPE A-C

DATE 2 Sept. 1958 AREA NO. A-14

PROCEDURE FH AREA SIZE 40' x 150'

(6000 sq. ft.)

I_R

5407	4928	4836	4652	4898	4806	4921	4401	3981	3161	3256
3202	3804	2921	3521	3107	3398	3916	3095	3441	3545	2352
3652	3754	3431	4291	4336	3409	4306	3787	2752	3317	3938

R_R

190	154	220	133	125	110	108	90	77	101	54
160	202	162	156	173	220	132	108	293	59	36
209	272	475	236	192	202	312	154	113	101	79

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-251 SURFACE TYPE A-C

DATE 13 Sept. 1958 AREA NO. A-19

PROCEDURE FH AREA SIZE 40' x 150' (6000 sq. ft.)

I_R

2304	2948	1958	3906	3016	852	5197	3440	4274	4215	3510
1853	4029	5844	5584	6248	2632	4595	2990	3300	3696	2036
2444	1283	2338	1957	3006	2880	5050	4310	4078	4416	4478

R_R

86	81	71	75	68	63	83	64	135	55	60
122	108	112	109	116	73	66	115	53	41	39
109	87	76	85	118	76	498	60	62	60	54

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-2511	SURFACE TYPE	A-C
DATE	18 Sept. 1958	AREA NO.	A-2
PROCEDURE	FH	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

4403	4874	5014	3981	4069	5377	4675	3873	3820	4055	3331
5469	4392	3921	4868	5803	3381	4211	4558	6074	5163	3903
4283	4763	5170	5245	3653	4159	3225	3985	4065	2939	5338

R_R

109	200	113	197	150	106	97	76	75	75	70
87	115	98	102	91	88	94	80	66	51	42
132	111	136	106	104	97	80	71	97	68	55

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-26

DATE 4 Sept. 1958

PROCEDURE FH

SURFACE TYPE A-C

AREA NO. A-21

AREA SIZE 40' x 150' (6000 sq. ft.)

I_R

10339	10919	12302	12164	13177	13304	11000	13650	12120	13445	11950
11600	13477	12855	12184	14593	11949	14230	14295	12405	14392	12635
12180	10566	13196	11794	11750	13126	11622	12516	12504	12266	12746

R_R

166	175	172	174	148	160	143	142	120	83	50
183	160	129	152	140	140	139	166	107	71	47
255	259	119	176	184	189	150	129	120	85	74

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-261	SURFACE TYPE	A-C
DATE	18 Sept. 1958	AREA NO.	A-12
PROCEDURE	FH	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

8651	9968	10467	8784	8381	9169	10484	10134	8519	8362	9821
9282	7758	8305	10131	10127	8508	7788	8542	9108	8436	6865
10116	11478	11346	9952	9987	10637	11163	10745	10060	9842	9818

R_R

200	151	166	158	106	96	77	84	107	81	78
161	179	143	142	129	212	116	95	113	79	74
172	172	153	142	136	136	133	121	108	124	61

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-27 SURFACE TYPE A-C

DATE 30 Aug. 1958 AREA NO. A-9

PROCEDURE FH AREA SIZE 40' x 150'
(6000 sq. ft.)

I_R

3638	3892	3802	3857	3760	3879	4557	4446	4207	4387	4506
3638	2718	3057	3193	3250	3925	3892	3459	3254	3159	4613
4128	3865	3784	4189	4774	4396	4384	4384	4319	3815	4151

R_R

567	400	296	445	118	984	154	516	830	725	1480
462	380	177	373	672	406	462	2090	1740	1860	432
984	246	655	437	746	1060	555	1020	1424	667	424

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO. A-28 SURFACE TYPE A-C

DATE 2 Sept. 1958 AREA NO. A-12

PROCEDURE FH AREA SIZE 40' x 150' (6000 sq. ft.)

I_R

3374	4426	4207	5230	3890	4592	4019	4666	3882	4541	3786
4934	5506	4973	5348	4893	5588	5136	5520	4882	4018	3401
4050	5901	4386	5543	4857	5485	4805	5434	4055	5107	4062

R_R

299	314	297	373	662	674	405	428	297	280	88
646	812	1390	570	482	336	230	229	325	261	93
239	251	1135	402	261	512	373	428	2160	660	239

TEST DATA SHEET
12ND NRDL-1000 (6/59)

TEST NO.	A-29	SURFACE TYPE	A-C
DATE	6 Sept. 1958	AREA NO.	A-13
PROCEDURE	FH	AREA SIZE	40' x 150' (6000 sq. ft.)

I_R

14972	13621	15238	13485	13239	14876	13870	13987	13773	13979	15642
16213	13435	13914	15612	12866	15353	13671	12583	15916	16200	15489
14400	14919	16709	15670	15908	14881	13103	11254	8865	13218	11258

R_R

384	228	714	243	236	185	171	143	229	162	73
493	324	1068	1066	499	259	206	189	371	161	88
343	319	3230	251	220	249	195	204	143	119	89

TEST DATA SHEET
12ND NRDL-1001 (6/59)

TEST NO.	A-30	SURFACE TYPE	P-C
DATE	5 Sept. 1958	AREA NO.	A-29
PROCEDURE	FH	AREA SIZE	40' x 100' (4000 sq. ft.)

I_R

2887	3717	3601	3862	4584	4723	4604	4376
2948	3929	3904	3539	3449	2939	3054	2936
3569	3240	3077	3315	3409	3386	3170	2946

R_R

109	154	114	83	83	105	137	46
129	72	104	74	74	195	75	42
82	70	58	83	53	69	34	77

TEST DATA SHEET
12ND NRDL-1002 (6/59)

TEST NO. A-31 SURFACE TYPE P-C

DATE 9 Sept. 1958 AREA NO. A-31

PROCEDURE FH AREA SIZE 32' x 140'

(4500 sq. ft.)

I_R

7009	12720	8929	12968	9016	11016	11916	13523	9692	13256	10285
3155	2570	8478	6489	9788	7172	9689	10946	11962	4852	8256

Seam

R_R

191	209	209	183	194	208	166	2331	134	127	116
145	131	139	137	173	144	183	1318	147	102	130

TEST DATA SHEET
12ND NRDL-1001 (6/59)

TEST NO. A-32
DATE 18 Sept. 1958
PROCEDURE FH
SURFACE TYPE P-C
AREA NO. A-29
AREA SIZE 40' x 100' (4000 sq. ft.)

I_R

7148	8370	9506	11385	12014	11120	9837	10005
13384	14807	10915	9869	10602	11326	9883	9667
11460	12286	11076	10640	10639	10845	12078	12882

R_R

202	218	139	126	116	108	103	78
148	101	114	101	145	138	113	131
138	116	103	104	133	94	92	54

TEST DATA SHEET
12ND NRDL-1004 (6/59)

TEST NO. A-40 SURFACE TYPE A-C

DATE 20 Sept. 1958 AREA NO. A-40

PROCEDURE Swpr-CMF AREA SIZE 32' x 200' (6400 sq. ft.)

I_R

		10273	10678	9803	10591	11266	11579	10932	9393	9736	10472	9650	8843
11754	10524	9340	9427	10215	11740	10263	9631	11134	9810	11304	11507	12772	10327

R_{R-1}

2240	1510	1190	1165	1005	1090	970	820	1175	1930	1024	1145	884	1235
765	1327	1355	3115	1265	2130	1465	1975	1920	3640	3255	2565	2770	3110

R_{R-2}

97	202	87	82	68	65	69	82	81	72	68	66	63	78
125	128	100	147	97	171	187	190	184	344	386	210	134	191

ROOFS

DATE 8 SEPT

TEST NO. AR1

AREA NO. AR 3 (603)

SIZE 30' X 48'

NO. STATIONS 15

PROCEDURE WATER BROOM

RATE 60 FT²/MIN

SURFACE TYPE TAR & GRAVEL

COND. FAIR

WIND DIRECTION NW

SPEED 1-2 KNOTS

BCKGRND CRCTN 0.5 cps

MID TIME:

INITIAL 0820

FINAL 1040

DIFF. 02:20

DECAY FACTOR 1.040

LEGEND:

+ station readings (cps)

O pan samples (g/ft^2)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

10 g/ft²

STREET

306.0	282.7	288.9
243.1	228.5	232.0
254.4	249.2	246.5
229.2	217.6	220.4
264.9	263.6	266.4

3793.4

$\bar{I}_r$ = 252.89 ± 26.1

13.2	10.9	8.8
13.8	13.6	10.6
10.4	8.4	6.6
19.3	14.5	10.1
15.5	11.1	9.8

176.6

$\bar{R}_r$ = 11.77 ± 3.2

.04	.04	.04
.06	.06	.05
.04	.03	.03
.08	.07	.05
.06	.04	.03

.72

$\bar{F}_r$ = .05 ±.014

ROOFS

DATE 17 SEPT

TEST NO. AR 2

AREA NO. AR 5 (602)

SIZE 30' x 48'

NO. STATIONS 9

PROCEDURE WATER BROOM

RATE 80 FT²/MIN

SURFACE TYPE TAR & GRAVEL

COND. FAIR

WIND DIRECTION SW VAR.

SPEED 3 ½ KNOTS

BCKGRND CRCTN 1.2 cps

MID TIME:

INITIAL 0828

FINAL 1048

DIFF. 02:20

DECAY FACTOR 1.040

LEGEND:

+ station readings (cps)

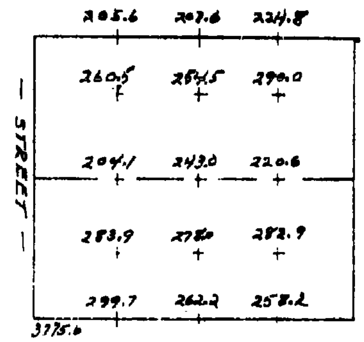
O pan samples (g/ft^2)

I_r initial readings (cps)

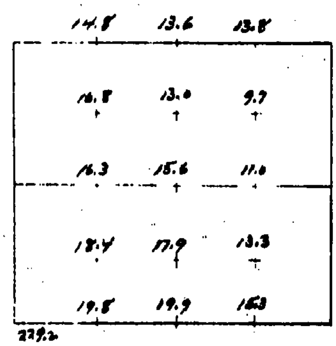
R_r residual readings (cps)

F_r fraction remaining

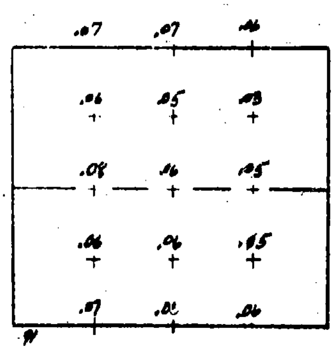
30 g/ft²



$\overline{I}_r$ = 261.70 ± 32.5



$\overline{R}_r$ = 16.28 ± 3.0



$\overline{F}_r$ = .06 ± .014

ROOFS

- DATE: 4 SEPT
- TEST NO.: AR 3
- AREA NO.: AR 1 (604)
  - SIZE: 30' x 48'
- NO. STATIONS: 15
- PROCEDURE: WATER BROOM
- RATE: 60 FT^2/MIN
- SURFACE TYPE: TAR & GRAVEL
  - COND.: FAIR
- WIND DIRECTION: NE
  - SPEED: 6 KNOTS
- BCKGRND CRCTN: 0.8
- MID TIME:
  - INITIAL: 0855
  - FINAL: 1250
  - DIFF.: 03:55
- DECAY FACTOR: 1.07

LEGEND:

- + station readings (cps)
- O pan samples (g/ft^2)
- I_r initial readings (cps)
- R_r residual readings (cps)
- F_r fraction remaining

100 g/ft^2

STREET

361.5	302.7	338.4
306.3	339.1	330.8
583.2	353.8	323.0
300.5	327.7	333.6
335.2	338.7	381.7

4663.0

$\bar{I}_r$ = 333.1 ± 21.6

7.2	7.9	8.3
7.3	6.5	6.6
8.1	10.5	6.6
8.9	8.5	5.7
11.1	13.9	10.6

127.7

$\bar{R}_r$ = 8.51 ± 2.2

.02	.03	.02
.02	.02	.02
.01	.03	.02
.03	.03	.02
.03	.04	.03

.37

$\bar{F}_r$ = .02 ± .014

ROOFS

DATE 8 SEPT

TEST NO. AR 4

AREA NO. AR 4 (603)

SIZE 30' x 40'

NO. STATIONS 15

PROCEDURE WATER BROOM

RATE 78 FT²/MIN

SURFACE TYPE TAR & GRAVEL

COND. FAIR

WIND DIRECTION NW

SPEED 10 KNOTS

BCKGRND CRCTN 0.8

MID TIME:

INITIAL 1355

FINAL 1625

DIFF. 02:30

DECAY FACTOR 1.044

LEGEND:

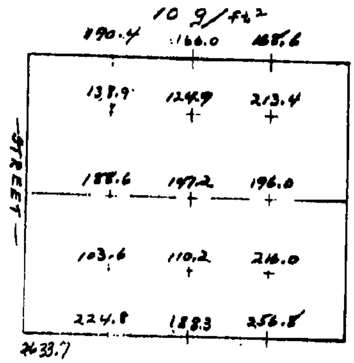
+ station readings (cps)

O pan samples (g/ft^2)

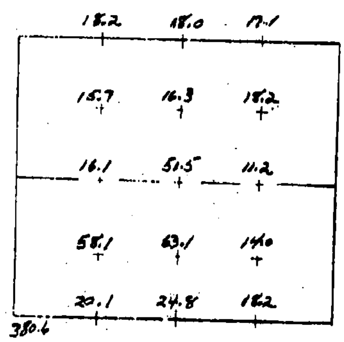
I_r initial readings (cps)

R_r residual readings (cps)

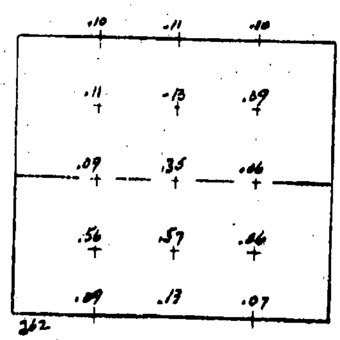
F_r fraction remaining



$\bar{I}_r$ = 175.58 ± 44.2



$\bar{R}_r$ = 25.37 ± 17.1



$\bar{F}_r$ = .17 ± .17

ROOFS

DATE *17 SEPT*

TEST NO. *AR 5*

AREA NO. *AR 2 (604)*

SIZE *30' x 40'*

NO. ST TIONS *15*

PROCEDURE *WATER BROOM*

RATE *107 FT² / MIN*

SURFACE TYPE *TAR & GRAVEL*

COND. *FAIR*

WIND DIRECTION *SW*

SPEED *3½ KNOTS*

BCKGRND CRCTN *0.6*

MID TIME:

INITIAL *0900*

FINAL *1030*

DIFF. *30 MIN*

DECAY FACTOR *1.009*

LEGEND:

+ station readings (cps)

O pan samples (g/ft²)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

30 g/ft²

— STREET —

182.7	198.5	190.3
248.1	252.2	242.8
205.5	217.0	218.7
259.0	259.2	248.6
223.3	224.6	198.0

3375.5

$\bar{I}_r$ = 224.90 ± 26.5

26.6	23.8	21.4
17.2	22.5	17.9
18.0	34.6	16.8
21.3	19.0	18.4
17.1	19.0	21.6

315

$\bar{R}_r$ = 21.01 ± 4.6

.15	.12	.11
.07	.09	.07
.09	.16	.08
.08	.07	.07
.08	.08	.11

1.49

$\bar{F}_r$ = .10 ± .028

ROOFS

DATE 13 SEPT

TEST NO. AR 6

AREA NO. AR 6 (602)

SIZE 30' × 40'

NO. STATIONS 15

PROCEDURE WATER BROOM

RATE 90 FT²/MIN

SURFACE TYPE TAR & GRAVEL

COND. FAIR

WIND DIRECTION W - SW

SPEED 7 KNOTS

BCKGRND CRCTN ~ 0.8 cps

MID TIME:

INITIAL 0943

FINAL 1448

DIFF. 05:03

DECAY FACTOR 1.09

LEGEND:

+ station readings (cps)

O pan samples (g/ft²)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

320.4	321.4	375.1
326.5	317.8	324.7
363.2	426.2	371.0
293.9	330.0	485.9
395.6	381.2	378.8

5364.7

$\overline{I}_r$ = 357.64 ± 50.8

28.1	36.3	36.2
25.2	40.5	52.3
20.5	38.6	83.6
28.4	38.8	38.6
20.3	36.6	38.6

480.9

$\overline{R}_r$ = 34.3 ± 8.7

.09	.11	.10
.08	.13	.16
.06	.09	.23
.08	.12	.08
.16	.12	.10

1.61

$\overline{F}_r$ = .11 ± .044

ROOFS

DATE 8 SEPT

TEST NO. AR 7

AREA NO. AR 7 (1221)

SIZE 30' X 33'

NO. STATIONS 15

PROCEDURE WATER BROOM

RATE 340 ml/ft²/MIN

SURFACE TYPE COMP. SHINGL

COND. GOOD

WIND DIRECTION W - NW

SPEED 10 KNOTS

BCKGRND CRCTN 0.7 CPS

MID TIME:

INITIAL 1505

FINAL 1535

DIFF. 30 MIN

DECAY FACTOR 1.009

LEGEND:

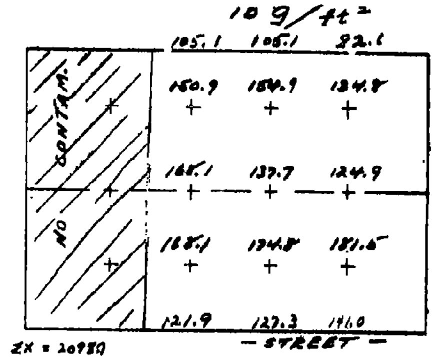
+ station readings (cps)

O pan samples (g/ft²)

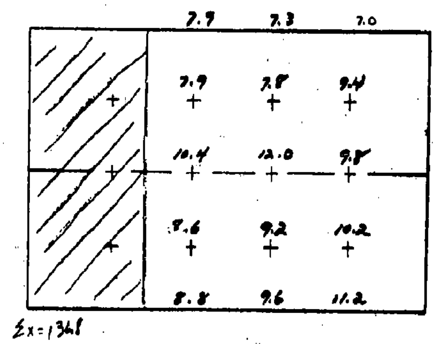
I_r initial readings (cps)

R_r residual readings (cps)

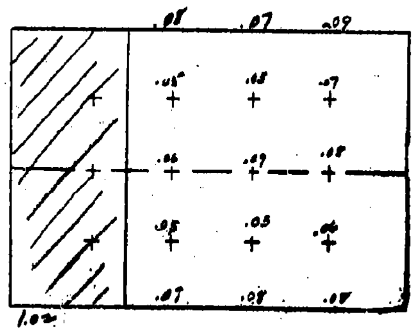
F_r fraction remaining



$\overline{I}_r$ = 137.6 ± 28.4



$\overline{R}_r$ = 9.12 ± 1.6



$\overline{F}_r$ = .07 ± .04

ROOFS

DATE 9 SEPT

TEST NO. AR 8

AREA NO. AR 11 (1369)

SIZE 30' X 50'

NO. STATIONS 20

PROCEDURE WATER BROOM

RATE 320 FT³/MIN

SURFACE TYPE COMP. SHINGL.

COND. GOOD

WIND DIRECTION SW

SPEED 10 KNOTS

BCKGRND CRCTN 0.8 cps

MID TIME:

INITIAL 0730

FINAL 0820

DIFF. 50 MIN

DECAY FACTOR 1.014

LEGEND:

+ station readings (cps)

○ pan samples (g/ft^2)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

30 g/ft²

4690	308.8	268.4	212.0
388.5	426.0	399.8	295.4
641.4	486.0	595.4	261.8
387.0	391.4	417.8	301.4
201.0	414.4	383.0	317.5

ΣX = 7566.0 — STREET —

$\overline{I}_r$ = 378.3 ± 114.3

18.0	22.5	23.2	20.5
16.0	22.3	24.2	18.2
16.8	22.5	30.0	23.0
20.5	20.6	26.0	18.9
24.8	27.5	25.4	22.4

446.3

$\overline{R}_r$ = 22.32 ± 3.8

.04	.07	.09	.10
.04	.05	.06	.06
.03	.05	.05	.09
.05	.05	.06	.06
.12	.07	07	.07

1.28

$\overline{F}_r$ = .06 ± .04

ROOFS

DATE 12 SEPT

TEST NO. AR 9

AREA NO. A 2 9 (1328 W)

SIZE 30 X 33

NO. STATIONS 15

PROCEDURE WATER BROOM

RATE 141 FT²/MIN

SURFACE TYPE COMP. SHINGL

COND. GOOD

WIND DIRECTION SW - VAR.

SPEED 3 - 9 KNOTS

BCKGRND CRCTN 1.3 cps

MID TIME:

INITIAL 1700

FINAL 1908

DIFF. 02:08

DECAY FACTOR 1.037

LEGEND:

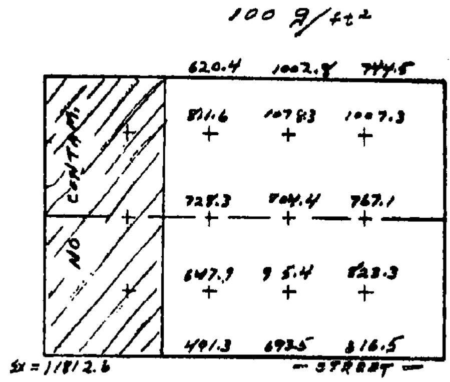
+ station readings (cps)

O pan samples (g/ft^2)

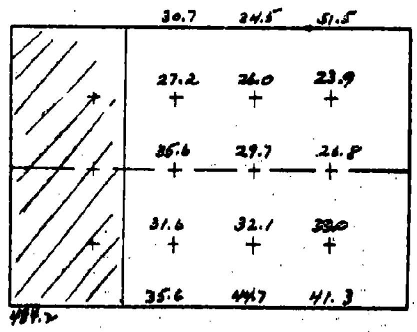
I_r initial readings (cps)

R_r residual readings (cps)

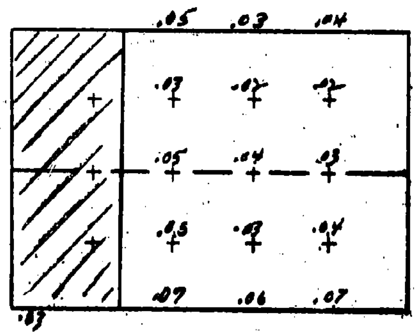
F_r fraction remaining



$\bar{I}_r$ = 787.50 ± 168.1



$\bar{R}_r$ = 32.28 ± 5.6



$\bar{F}_r$ = .041 ± .017

ROOFS

DATE 15 SEPT

TEST NO. AR 10

AREA NO. A2 12 (1379)

SIZE 30' x 50'

NO. STATIONS 20

PROCEDURE WATER BROOM

RATE 640 FT²/MIN

SURFACE TYPE COMP. SHINGL

COND. GOOD

WIND DIRECTION N-NW

SPEED 2

BCKGRND CRCTN 0.6

MID TIME:

INITIAL 0928

FINAL 1400

DIFF. 04:32

DECAY FACTOR 1.080

LEGEND:

+ station readings (cps)

O pan samples (g/ft^2)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

10 g/ft²

49.4	49.3	61.5	62.9
99.0	98.7	100.6	82.0
72.0	78.2	89.6	85.1
112.8	117.4	108.4	96.3
83.2	80.3	79.6	87.8

Ex = 162.81

$\overline{I}_r =$ 81.40 ± 22.3

7.4	8.6	6.9	5.2
7.8	8.7	5.6	6.6
6.6	8.0	8.9	5.8
9.1	10.4	9.5	8.6
11.4	18.0	13.0	10.8

170.9

$\overline{R}_r =$ 8.64 ± 2.3

.15	.17	.13	.08
.08	.09	.06	.07
.09	.10	.10	.07
.08	.09	.09	.09
.14	.16	.16	.29

2.00

$\overline{F}_r =$ .10 ± .037

ROOFS

DATE 9 SEPT

TEST NO. AR 11

AREA NO. AR 8 (1311)

SIZE 30' x 50'

NO. STATIONS 20

PROCEDURE WATER BROOM

RATE 455 FT^2/MIN

SURFACE TYPE COMP. SHINGL.

COND. GOOD

WIND DIRECTION SW

SPEED 6-7 KNOTS

BCKGRND CRCTN 1.5

MID TIME:

INITIAL 1145

FINAL 1328

DIFF. 01:43

DECAY FACTOR 1.03

LEGEND:

- \+ station readings (cps)
- O pan samples (g/ft^2)
- I_r initial readings (cps)
- R_r residual readings (cps)
- F_r fraction remaining

30 g/ft^2

307.2	262.8	277.9	270.9
256.7	399.8	369.7	363.1
271.9	304.0	302.7	283.1
344.7	416.0	408.3	388.7
233.5	343.2	345.9	311.2

Σ: 6471.3 — STREET —

$\bar{I}_r$ = 323.56 ± 54.8

16.8	26.6	30.0	30.2
15.4	22.1	23.8	23.8
18.4	21.5	27.3	24.4
19.3	20.3	29.7	26.2
24.7	26.2	34.1	30.7

488.5

$\bar{R}_r$ = 24.42 ± 5.0

.05	.09	.11	.11
.06	.06	.06	.08
.07	.07	.09	.09
.06	.05	.07	.06
.11	.07	.10	.10

1.54

$\bar{F}_r$ = .08 ± .02

ROOFS

DATE: 13 SEPT.

TEST NO. AR 12

AREA NO. AR 10 (1328 E)

SIZE: 30' x 50'

NO. STATIONS: 20

PROCEDURE: WATER BROOM

RATE: 400 FT²/MIN

SURFACE TYPE: COMP SHINGL

COND.: GOOD

WIND DIRECTION: N - NW

SPEED: 2 KNOTS

BCKGRND CRCTN: 3.5

MID TIME:

INITIAL: 1028

FINAL: 1338

DIFF.: 03:10

DECAY FACTOR: 1.055

LEGEND:

+ station readings (cps)

O pan samples (g/ft^2)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

100 g/ft²

198.3	387.9	177.3	183.1
254.7	258.8	298.7	274.2
370.5	348.6	364.7	362.3
328.7	371.3	378.2	464.8
256.7	360.5	363.3	277.3

Σx: 6267.8

— STREET —

$\bar{I}_r = 313.39 \pm 78.9$

10.4	11.2	11.3	11.1
12.0	9.1	9.8	8.8
21.0	15.0	12.9	12.7
32.0	24.6	21.0	18.7
51.2	34.1	33.0	26.9

385.8

$\bar{R}_r = 19.29 \pm 11.2$

.05	.03	.06	.06
.05	.04	.03	.03
.06	.04	.04	.03
.10	.07	.06	.04
.20	.09	.09	.09

1.06

$\bar{F}_r = .06 \pm .022$

ROOFS

DATE *15 SEPT*

TEST NO. *AR 13*

AREA NO. *AR 13 (1388)*

SIZE *1665 FT²*

NO. STATIONS *9*

PROCEDURE *LOBBING 1½ FH*

RATE *250 FT³/MIN*

SURFACE TYPE *COMP SHINGL*

COND. *GOOD*

WIND DIRECTION *—*

SPEED *0*

BCKGRND CRCTN *0.6*

MID TIME:

INITIAL *0835*

FINAL *1423*

DIFF. *5:48*

DECAY FACTOR *1.099*

LEGEND:

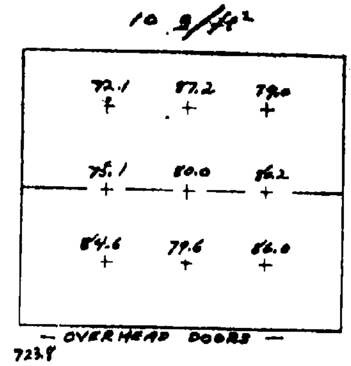
+ station readings (cps)

O pan samples (g/ft^2)

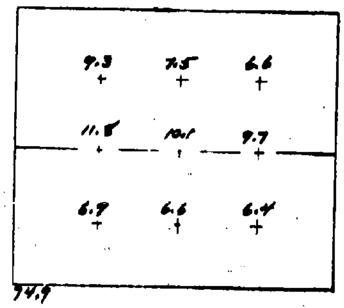
I_r initial readings (cps)

R_r residual readings (cps)

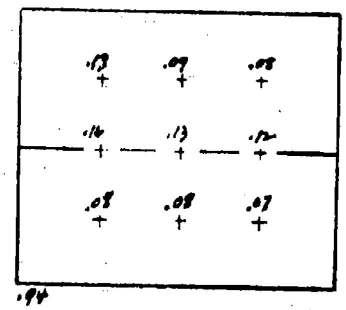
F_r fraction remaining



$\bar{I}_r$ = *80.4 ± 4.9*



$\bar{R}_r$ = *8.32 ± 1.95*



$\bar{F}_r$ = *.10 ± .031*

ROOFS

DATE 19 SEPT

TEST NO. AR 14

AREA NO. AR 13 (1388)

SIZE 1620 FT²

NO. STATIONS 9

PROCEDURE LOBBING 1½ FH

RATE 265 FT²/MIN

SURFACE TYPE COMP. SHINGL.

COND. GOOD

WIND DIRECTION S

SPEED 1-2 KNOTS

BCKGRND CBCTN 2.8

MID TIME:

INITIAL 0938

FINAL 1115

DIFF. 01:37

DECAY FACTOR 1.028

LEGEND:

+ station readings (cps)

O pan samples (g/ft^2)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

30 g/ft²

119.3	181.4	124.0
111.4	126.4	104.1
115.8	173.2	132.0

— OVERHEAD DOORS —

1187.6

$\bar{I}_r$ = 131.95 ± 27.1

10.9	6.6	4.7
7.7	3.9	5.3
3.5	2.7	2.8

48.1

$\bar{R}_r$ = 5.34 ± 2.7

.09	.04	.04
.07	.03	.05
.03	.02	.02

.39

$\bar{F}_r$ = .04 ± .024

ROOFS

DATE 25 AUG.

TEST NO. AR 15

AREA NO. AR 13 (1388)

SIZE 1708

NO. STATIONS 9

PROCEDURE LOBBING 1½ FH

RATE 190 FT.²/MIN

SURFACE TYPE COMP. SHINGL.

COND. GOOD

WIND DIRECTION NW

SPEED 8-10 KNOTS

BCKGRND CRCTN 0.3

MID TIME:

INITIAL 1457

FINAL 1545

DIFF. 48 MIN

DECAY FACTOR 1.016

LEGEND:

+ station readings (cps)

O pan samples (g/ft^2)

I_r initial readings (cps)

R_r residual readings (cps)

F_r fraction remaining

100 g/ft²

406.5	404.1	445.8
332.7	278.8	310.7
351.2	369.5	415.0

— OVERHEAD DOORS —

3314.3

$\overline{I}_r$ = 368.25 ± 54.6

10.7	9.5	11.3
11.3	6.5	16.1
26.1	25.7	19.7

135.9

$\overline{R}_r$ = 15.10 ± 7.3

.03	.02	.03
.03	.02	.05
.07	.07	.05

.37

$\overline{F}_r$ = .04 ± .02

APPENDIX C

CONVERSION OF RADIATION MEASUREMENTS TO MASS UNITS

C.1 A calibration factor for the mobile shielded detector was established for each surface; this calibration factor was then used to calculate a conversion factor for determining mass levels. The complete derivation of these factors is discussed in detail in Vol. I of this series of reports.

$$k = \frac{I_r}{M_D \times S} \tag{C.1}$$

where k = calibration factor, counts per disintegration per square foot ($c/d/ft^2$), accounting for surface roughness and backscattering

I_r = average initial intensity of contaminated surface, in counts per minute (c/m) obtained with mobile shielded detector

M_D = average weight of contaminant, in grams per square foot (g/ft^2) determined by 1.22 ft^2 pan samples

S = specific activity, in disintegrations per second per gram $\left(\frac{d/s}{g}\right)$ measured in a 4-pi ionization chamber.*

As can be seen from Table C.1 a considerable variation in the value of k was found. This variation is attributed primarily to instrument error or variability and to rearrangement of the contaminant by the wind between successive measurements. A k of constant value, denoted as k_o, was determined for each surface by a simple average of all suitable values. To determine mass levels using k_o

$$k_o \times S = C \tag{C.2}$$

$$\frac{I_r}{C} = M_o \tag{C.3}$$

*The calibration factor[8] used for converting the readings from the 4-pi ion chamber from milliamperes to disintegrations per second is:

$$3.30 \times 10^{-15} \frac{ma}{d/m}$$

$$\frac{R_r}{C} = M \qquad (C.4)$$

where C = a conversion factor, $\frac{c/s}{g/ft^2}$

M_o = calculated initial mass, g/ft^2

R_r = average residual intensity of decontaminated surface, in c/m

M = calculated residual mass, g/ft^2

TABLE C.1

Compilation of Basic and Extracted Test Data: From Pavements

Test	Area	Date	Mix[(a)] Number	1 Time	2 Wind Speed Knots	3 M_D g/ft^2	4 Pan Counts $c/m/ft^2$	5 S $d/s/g$ $\times 10^5$	6 c/d $\times 10^{-4}$	7 k $c/d/ft^2$	8 k_o $\times 10^{-4}$	9 C $\frac{c}{s}/\frac{g}{ft^2}$	10 I_r c/s	11 M_{O_2} g/ft^2	12 R_r c/s	13 M g/ft^2
									Conventional Motorized Flushing							
A1	A17	8/27	2.3	0812	6	21.9	82,464	4.172	1.45	5.671	5.870	244.89	5,181	21.2	211	0.86
A2	A22	8/21	1.4	1032	5	39.3	67,708	1.889	1.50	5.079	5.870	110.88	3,767	34.0	161	1.45
A3	A23	8/25	2.1	0805	7	89.5	152,146	2.036	1.41	5.506	5.870	119.51	10,031	83.9	94	0.79
A4	A14	8/30	2.6	0848	4	16.6	45,930	3.243	1.41	8.122	5.870	190.36	4,383	23.02	265	1.39
A5	A10	9/15	5.1	1142	5	43.6	119,335	3.158	1.44	4.703	5.870	185.37	6,473	34.7	262	1.41
A51	A19	9/16	5.2	0857	5	31.3	85,199	3.185	1.42	5.303	5.870	186.96	5,282	28.2	186	0.99
A6	A19	8/25	2.1	1052	9	89.9	148,231	1.916	1.42	5.236	5.870	112.47	9,020	80.2	197	1.75
A7	A1	8/30	2.6	0915	4	18.3	51,256	3.264	1.42	7.077	5.870	191.60	4,435	23.1	350	1.83
A8	A16	8/30	2.6	1100	4	52.7	166,415	3.13	1.42	6.345	5.870	183.73	10,462	56.9	429	2.34
A81	A16	9/19	5.5	0900	2	41.3	65,267	1.821	1.44	5.517	5.870	106.89	4,153	38.8	114	1.07
A9	A10	8/26	2.2	0818	2	128.6	129,664	1.282	1.39	5.059	5.870	75.25	8,340	110.8	433	5.75
A10	A30	9/19	5.5	0747	2	13.8	24,154	1.924	1.39	7.451	6.290	121.02	1,977	16.3	85	0.70
A11	A31	9/16	5.2	0922	1	27.9	75,609	3.158	1.43	8.458	6.290	198.64	7,444	37.5	99	0.49
A12	A30	9/1	3.1	0700	4	197.8	268,198	1.534	1.48	4.069	6.290	96.49	12,343	127.9	195	2.02
A13	A32	9/13	4.5	0740	5	11.7	25,621	2.438	1.49	8.365	5.870	143.11	2,386	16.7	88	0.61
A14	A32	9/20	5.6	0830	2	109.4	166,844	1.848	1.41	5.503	5.870	108.48	11,125	102.6	95	0.88
A40	A40	9/20	5.6	0710	5	153.0	196,466	1.267	1.46	5.415	5.870	74.37	10,499	141.2	1715	23.06
A40	A40	9/20	-	-	-	-	-	-	-	-	-	-	-	-	125	1.68
									Improvised Motorized Flushing							
A15	A6	9/15	5.1	0735	1	17.6	49,844	3.309	1.41	6.850	5.870	194.24	3,994	20.6	239	1.23
A16	A8	8/29	2.5	0800	6	61.4	163,848	3.141	1.43	5.361	5.870	184.38	10,348	56.1	277	1.50
A17	A18	9/1	3.1	0740	1	166.2	226,052	1.504	1.50	5.078	5.870	88.28	12,153	137.6	198	2.24
A18	A7	9/5	3.5	0745	2	18.7	50,821	3.068	1.48	7.013	5.870	180.09	4,030	22.4	215	1.19
A19	A18	9/17	5.3	0740	11	29.6	91,337	3.576	1.40	4.960	5.870	209.91	5,250	25.0	131	0.62
A20	A11	9/10	4.3	0705	10	159.4	267,179	1.891	1.47	4.745	5.870	111.00	14,336	129.2	262	2.36
A201	A15	9/13	4.6	0837	7	83.2	141,516	1.928	1.47	6.152	5.870	113.17	9,870	87.2	180	1.59
A21	A30	9/15	5.1	1022	1	18.7	51,280	3.218	1.41	7.381	6.290	202.41	4,449	22.0	167	0.83
A22	A30	9/17	5.3	0718	5	28.8	80,556	3.570	1.40	5.526	6.290	224.55	5,683	25.3	109	0.49
A23	A30	9/13	4.6	0812	4	110.4	189,993	1.984	1.44	4.830	6.290	124.79	10,582	84.8	126	1.01
									Firehosing							
A24	A20	8/30	2.6	0645	1	18.3	56,739	3.42	1.42	6.537	5.870	200.75	4,087	20.4	139	0.69
A25	A14	9/2	3.2	0657	4	43.5	57,288	1.504	1.46	5.863	5.870	88.28	3,834	43.4	154	1.74
A251	A19	9/13	4.6	1052	7	23.5	36,250	1.742	1.48	8.481	5.870	102.26	3,475	34.0	81	0.79
A2511	A2	9/18	5.3	0708	2	29.0	58,819	2.376	1.42	6.422	5.870	139.47	4,425	31.7	98	0.70
A26	A21	9/4	3.4	0747	3	151.0	201,128	1.537	1.44	5.395	5.870	90.22	12,523	138.8	143	1.59
A261	A12	9/18	5.4	0913	1	98.0	147,415	1.708	1.45	5.661	5.870	100.26	9,477	94.5	127	1.27
A27	A9	8/30	2.6	0712	1	19.4	57,041	3.329	1.46	6.076	5.870	195.41	3,918	20.0	721	3.69
A28	A12	9/2	3.2	0725	6	49.6	61,737	1.477	1.46	6.390	5.870	86.70	4,682	54.0	437	5.04
A29	A13	9/6	3.6	0735	1	178.1	235,619	1.461	1.51	5.451	5.870	85.76	14,185	165.4	301	3.51
A30	A29	9/5	3.5	0815	3	19.8	38,275	2.981	1.49	6.026	6.290	187.50	3,548	18.9	88	0.47
A31	A31	9/9	4.2	0950	8	38.2	113,557	3.379	1.46	7.172	6.290	212.54	9,258	43.6	158	0.74
A32	A29	9/18	5.4	0822	2	122.8	187,334	1.698	1.50	5.230	6.290	106.80	10,906	102.1	121	1.13

(a) First numeral refers to week; second numeral to day.
(b) Extrapolated value.
(c) These values not used for obtaining k_o.

TABLE C.2

Compilation of Basic and Extracted Data: From Roofs

Test	Area	Date	Mix[a] Number	1 Time	2 Wind Speed knots	3 M_D g/ft^2	4 Pan Counts c/m/ft^2	5 S d/s/g X 10^5	6 c/d X 10^4	7 k c/d/ft^2	8 k_o X 10^{-4}	9 C $\frac{c}{s}/\frac{g}{ft^2}$	10 I_r c/s	11 M_o g/ft^2	12 R_r c/s	13 M g/ft^2
30° Fan Nozzle on Tar and Gravel																
AR-1	AR-3	9/8		0820	1-1/2	28.0		3.210[b]	1.45	2.83	2.81	9.02	252.9	28.0	11.77	1.30
2	5	9/17		0828	3-1/2	25.6		3.506	1.43	2.70	2.81	9.84	251.7	25.6	15.28	1.55
3	1	9/4		0853	6	91.5		1.362	1.46	3.21	2.81	3.82	349.7	91.6	8.51	2.22
4	4	9/8		1350	10	21.1		2.954	1.50	2.96	2.81	8.35	175.6	21.1	25.37	3.05
5	2	9/17		0900	3-1/2	22.9		3.499	1.42	2.57	2.81	9.83	224.9	22.9	21.01	2.14
6	6	9/13		0942	7	65.2		1.948	1.45	2.60	2.81	5.48	357.6	65.2	37.63	6.87
30° Fan Nozzle on Composition Shingles																
AR-7	AR-7	9/8		1505	10	20.6		2.913	1.51	2.13	2.31	6.73	138.6	20.6	9.12	1.36
8	11	9/9		0730	10	43.7		3.750[b]	1.44	2.22	2.31	8.65	378.3	43.7	22.32	2.58
9	9	9/12		1700	6	102.0		3.345[b]	1.41	2.28	2.31	7.72	787.5	102.0	32.28	4.18
10	12	9/15		0928	2	10.8		3.260	1.47	2.22	2.31	7.53	81.4	10.8	8.54	1.13
11	8	9/9		1145	6-1/2	40.0		3.497[b]	1.45	1.79[c]	2.31	8.08	323.6	40.0	24.42	3.02
12	10	9/13		1028	2	71.8		1.890	1.49	2.20	2.31	4.36	313.4	71.8	19.29	4.43
Lobbing of Fire Streams on Composition Shingles																
AR-13	AR-13	9/15		0835	0	8.8		3.314	1.44	2.79	2.77	9.18	80.4	8.75	8.32	0.91
14	13	9/19		0938	1-1/2	26.2		1.821	1.43	2.75	2.77	5.04	132.0	26.19	5.34	1.06
15	13	8/25		1507	9	73.9		1.800	1.44	1.53[c]	2.77	4.98	368.2	73.93	15.10	3.03

(a) First numeral refers to week; second numeral to day.
(b) Extrapolated value.
(c) These values not used for obtaining k_o.

Explanation of Tables C.1 and C.2

(1) Time. Time that initial reading was taken; all radiation data have been decayed to this time.

(2) Wind Speed. Wind speed at time (1) obtained with a hand held anemometer.

(3) M_D. The average weight of the contaminant deposited per square foot by the dispersal device. The contaminant was collected in 1.22 ft^2 pans placed approximately every 500 ft^2 in the contamination pattern.

(4) Pan Count. The average one minute count determined in a large scale counter for the pan sample (normalized to 1 ft^2).

(5) S. Specific activity determined by 4-pi ion chamber on a sample taken from pan (3) above.

(6) c/d. The ratio of $\frac{(4)/(60)}{(3) \times (5)}$; c/d should be a constant value for all cases.

(7) k. Calculated value. $k = \frac{(10)}{(3) \times (5)}$; K should be a constant value for all like surfaces.

(8) k_o. Average value of k.

(9) C. A conversion factor dependent upon specific activity (5) and K_o(8).

(10) I_r. Average initial count of the test area taken with the mobile shielded detector.

(11) M_o. Average initial mass level; the ratio of (10)/(9).

(12) R_r. Average residual count on the test area taken with the mobile shielded detector.

(13) M. Average residual mass level; the ratio of (12)/(9).

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